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ENGINEER RESEARCH AND DEVELOPMENT LABORATORIES

Report 1161

Final Report

PRINTER, PHOTOGRAPHIC, HORIZONTAL PROJECTION, RECTIFYING, TILTS UNDER 70°, FOR 9½-INCH AERIAL ROLL FILM

Project 8-35-03-001

13 March 1950

Submitted to

THE CHIEF OF ENGINEERS, U. S. Army

by

The Commanding Officer
Engineer Research and Development Laboratories

Prepared by

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SUMMARY

This report covers an investigation involving the development, testing, and standardization of a lightweight, portable, horizontal, rectifying projection printer, mounted in a truck or trailer, for use in rectifying 9- by 9-inch, 6-inch focal length photography with tilts up to 70°, and 9- by 9-inch, 12-inch focal length photography with tilts up to 30° from the vertical.

The report concludes that the modified Bausch and Lomb rectifier conforms to the requirements of the military characteristics for this development. The instrument is suitable for standardization as adopted type, standard type, and as a Class IV item of supply. Personnel normally assigned to topographic units are capable of operating the modified Bausch and Lomb rectifier.

The report recommends that the modified Bausch and Lomb rectifier be standardized as adopted type, standard type, and be stocked as a Class IV item of supply, and that this project be closed.

FINAL REPORT

PRINTER, PHOTOGRAPHIC, HORIZONTAL PROJECTION, RECTIFYING, TILTS UNDER 70°, FOR 9½-INCH AERIAL ROLL FILM

I. INTRODUCTION

1. Subject. This report covers an investigation involving the development, testing, and standardization of a lightweight, portable, horizontal, rectifying projection printer mounted in a truck or trailer, for use in rectifying 9- by 9-inch, 6-inch focal length photography with tilts up to 70°, and 9- by 9-inch, 12-inch focal length photography with tilts up to 30° from the vertical.

2. Authority. This work was carried out under the authority of Project 8-35-03-001, "Rectifying Camera." A copy of the project card for this development (RDB Form 1A) is contained in Appendix A to this report.

3. Previous Investigations. During the last war (late 1942 -- early 1943), there developed an urgent requirement for rectification equipment to handle combat photography furnished (by the Air Force) in lieu of, or to supplement mapping photography. At that time, the only instrument available for rectification of tilted photography was one which had been manufactured by the Fairchild Aerial Surveys, Incorporated, for their own use. Several of these instruments were procured as a stop-gap measure. Later, after reports of deficiencies were received from the field, specifications incorporating certain modifications were prepared, and additional models of the improved type were procured from Photogrammetric Instruments Corporation, Pasadena, California, a subsidiary of the Fairchild Aerial Surveys, Incorporated. This instrument ESN. 18-5730.500-500 accommodated only a limited range of tilts (approximately 22° for 6-inch focal length photography and 35° for 12-inch focal length photography) and was found to be unsuitable for quantity production of controlled mosaics.

About the same time, an investigation was initiated by the ERDL for developing methods and equipment that would use tri-metrogon aerial photography to maximum advantage both in the compilation of original aeronautical charts and strategic maps, and in the revision of all types of maps and charts.

In prosecuting one phase of this investigation, a study was made of the practicability of using rectified tri-metrogon aerial photography and attendant compilation techniques for this purpose. A rectifier, constructed at the ERDL, was designed to rectify as a

minimum the following types of photography: 9- by 9-inch, 6-inch focal length tri-metrogon obliques, with tilts up to 70°; and 9- by 18-inch, 24-inch focal length photography of the tri-K-18 camera installation, with tilts up to 42°. In addition, the instrument was to be capable of reductions or enlargements ranging from 0.9 to 1.1 diameters, at the various angles of rectification. The investigation of this instrument is covered in ERDL Report, Rectifying Projection Camera Constructed at the Engineer Board, 17 December 1943.

Tests were also conducted utilizing the rectified tri-metrogon photography. These, which indicated that this procedure had considerable merit and advantages over the standard procedure being used, are covered in ERDL Report 830, Military Mapping from Tri-Metrogon Aerial Photography Using Rectified Photographs, 17 June 1944.

From the data obtained in both these investigations, the requirements for a suitable instrument were ascertained, and military characteristics were prepared to provide an instrument capable of rectifying (1) near vertical photography for mosaic compilation, (2) the split vertical 12-inch focal length photography being furnished by Air Force as supplemental coverage for mapping, and (3) the oblique photography of the tri-metrogon system. The military characteristics as finally approved are shown on the project card in Appendix A and are also given in Appendix B, together with added information required for standardization.

4. Personnel. The development work on this project was accomplished by John T. Pennington, and the inspection and tests by Frank A. McFarland, Photogrammetric Branch. All work was under the supervision of William C. Cude, Chief, Topographic Engineering Department.

II. INVESTIGATION

5. General. The representatives of several firms were contacted and requested to submit bids for the development and construction of an experimental model instrument which would conform with the approved military characteristics. Development contracts were awarded to the Rutherford Machinery Company of Rutherford, New Jersey, the Aero Service Corporation of Philadelphia, and the Bausch and Lomb Optical Company of Rochester. This development was carried on during the war years; therefore, because of the demand for accomplishing work of higher priority, and because of the lack of materials, and the shortage of personnel, progress was extremely slow. As a result, the Rutherford Machinery Company contract was finally cancelled; also, the Aero Service Corporation and the Bausch and Lomb Optical Company were unable to make deliveries of their finished

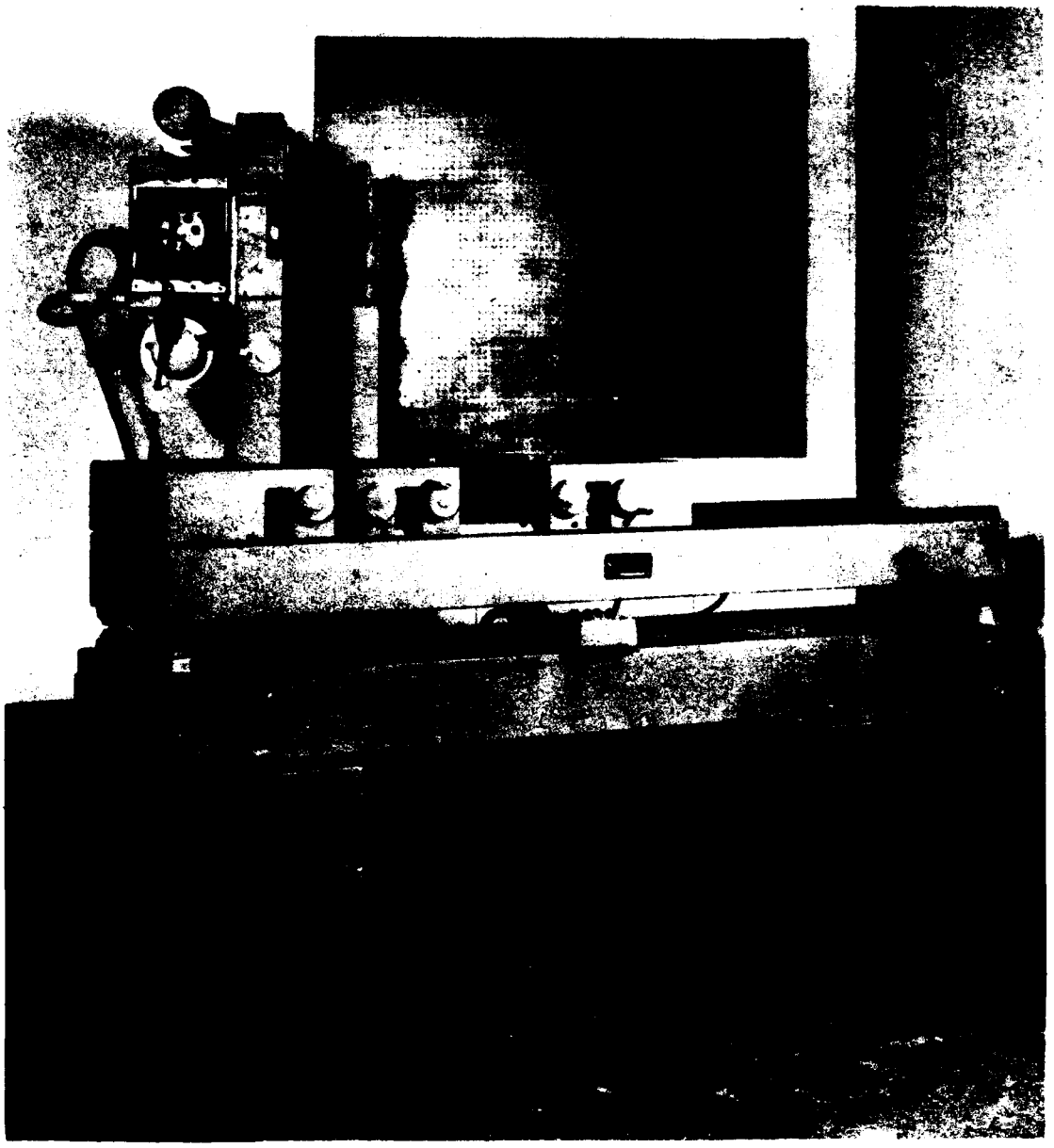

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Fig. 1. Experimental rectifier constructed by Aero Service Corporation.

instruments until October 1945 and July 1946, respectively. Comparative tests were run on both designs and it was found that neither instrument was entirely satisfactory for its intended purpose. However, the test provided a basis for modifying the more suitable of the two. This modification was accomplished by means of a purchase order placed with Fred P. Willcox, Bethesda, Maryland. The modified instrument was then further tested and is the end product that is evaluated by this report.

6. Description of Aero Service Corporation Rectifier. Fig. 1 shows an assembled view of the instrument constructed by the Aero Service Corporation. This instrument is of the horizontal projection type, with the negative, lens, and easel planes mounted on vertical axes. The lens and easel planes may be translated (moved) along the horizontal tracks or ways, and the negative may be swung through 360° in its own plane. The angular and linear motions are accomplished manually. Appropriate scales are provided for setting the instrument to predetermined data; all settings are made with respect to a base direction or reference line (the line between the principal point of the negative and the nodal point of the lens).

The instrument is designed so that it may be readily broken down into six principal sub-assemblies: the base, the easel and easel carriage, the lens carriage, the negative carriage, the illumination unit, and the projection lenses. The complete instrument weighs 564 pounds and is packed in four carrying chests which may be used as a supporting table as shown in Fig. 1. All motions are equipped with scales illuminated by ruby lamps. The angular motions are provided with 5-minute verniers and the linear motions have 0.1-mm verniers. A detailed description of the component parts follows:

a. Base. The base is an aluminum casting containing two precisely machined inverted "V" rails cast integrally with the base. The lens and easel carriages are translated along the tracks by means of pinion gears that engage a rack gear positioned in the center of the casting. A scale (graduated in millimeters) is positioned on the front of the casting and measures the movement of the lens and easel carriages. The aluminum casting (base) is supported by four heavy duty rubber grommets.

b. Easel and Easel Carriage. The easel is a cast aluminum shell 37 by 32 by 4½ inches in size; it is pierced with holes 1/16 inch in diameter spaced on ½-inch centers over the entire front surface. The easel is canted about a vertical axis through its front surface, by means of a hand wheel on the side of the easel carriage; a second hand wheel is provided for translation along the base. The easel carriage is supported on the base by bronze oilite bearing pads. The vacuum that holds the printing paper flat

against the surface of the easel is created by a 3/4-hp Victor-Acme rotary positive pressure blower connected to the easel frame by a flexible tube 3 inches in diameter. The blower assembly also contains the transformers required for the operation of the light source.

c. Lens Carriage. The lens carriage is similar in design and construction to the easel carriage; the rotational, translational, and support features are identical. The framework (carriage) supporting the bellows rotates independently of the shaft supporting the lens; in addition, a cross slide arrangement is provided so that the bellows will seek its own position when the negative and lens carriages are canted. A manually operated disk, positioned in front of the lens, is provided with a clear aperture for exposure and with a red filter for use in orienting photographic paper on the easel.

d. Negative Carriage. The negative carriage, of cast aluminum construction, is designed so that the negative plane is rotated about a vertical axis positioned at a distance of 1/3 the thickness of the stage glass in front of the negative in order to correct for refraction in the stage glass. The negative is canted about a vertical axis through its front surface by the hand wheel on the side of the carriage, and swung about a horizontal axis through the face of the negative by the hand wheel located in the negative frame. Supports attached to the framework of the carriage are provided for mounting standard aerial film spools; in addition, a specially designed micrometer-type device is provided on the spool mount for aligning the negative with the collimating marks on the negative stage glass. The film is flattened on the stage by a pressure glass which may be readily removed from the instrument if desired.

e. Illumination. The aluminum alloy light box is hinged to the negative carriage so that it rotates with the negative. Four 100-watt, high-pressure mercury vapor lamps are mounted in the light box behind a flashed opal glass diffuser. Because the mercury vapor lamps radiate considerable heat, forced draft ventilation is necessary and this is supplied by a fan operated by a 1/30-hp motor mounted on the side of the light box. The lamps must be burned continuously when the instrument is in operation as approximately 4 minutes are required for them to reach their full intensity, and because they will not light while hot. Consequently, a curtain shutter arrangement, which closes when the box is swung away from the negative, has been provided on the front of the light box to block out transmitted light.

f. Lenses. Two lenses are supplied with this instrument: a 4½-inch focal length Baker Hypergon for use in rectifying

the high oblique negatives, and a 7½-inch focal length Bausch and Lomb Protar V for near vertical rectification. The 4½-inch lens was specially designed for rectification by Dr. Baker of the Harvard Observatory, and is of symmetrical Hypergon design, nominally free of distortion. This lens is unique in that it has a canted diaphragm stop, f:22 aperture ratio. The 7½-inch Bausch and Lomb Protar V is a stock f:18 lens designed for wide-angle camera applications, but may be used as a process lens.

7. Description of Bausch and Lomb Optical Company Rectifier. Fig. 2 shows the Bausch and Lomb instrument set up for operation. The general principles of design for this instrument are similar to those of the Aero Service rectifier, as are the main components of the two rectifiers. The instrument weighs 530 pounds and is packed in two carrying chests. All motions are hand operated, the angular scales being equipped with verniers allowing direct reading to the nearest minute of arc, while the linear scales have verniers reading to the nearest 0.1 mm.

a. Base. The base of the instrument consists of two polished steel tubes permanently mounted in cast aluminum blocks supported by four detachable steel tube legs, two of which are adjustable for leveling. The lens and easel carriages are translatable along the tubes; large motions are manually made, while accurate settings are made by a clamp and slow motion screw. A linear millimeter scale extends along the base.

b. Easel and Easel Carriage. The easel is a cast aluminum shell 40 by 30 by 1 5/8 inches; it is pierced with holes 3/64 inch in diameter spaced on about 5/8-inch centers. The easel is connected to a deep bearing in the easel carriage to permit rotation about a vertical axis through its front surface. Large rotations of the easel are accomplished manually, and a clamp and tangent screw arrangement is provided for accurate settings. The easel carriage is supported on the tubular ways by two "V" rollers on one side and by a plane face roller on the other. Vacuum is supplied by a 1/3-hp Bruers Tornado blower connected to the easel frame by a 1½-inch flexible rubberized tube.

c. Lens Carriage. The lens carriage, also of cast aluminum construction, is supported on the tubular ways in a manner similar to that of the easel carriage. It is designed so that the lens may be rotated about a vertical axis through the entrant node of the lens. The lens mount is provided with positioning studs to facilitate the interchanging of projection lenses. The framework supporting the bellows rotates independently of the shaft supporting the lens, so that the bellows will seek its own position when the lens and negative planes are canted.

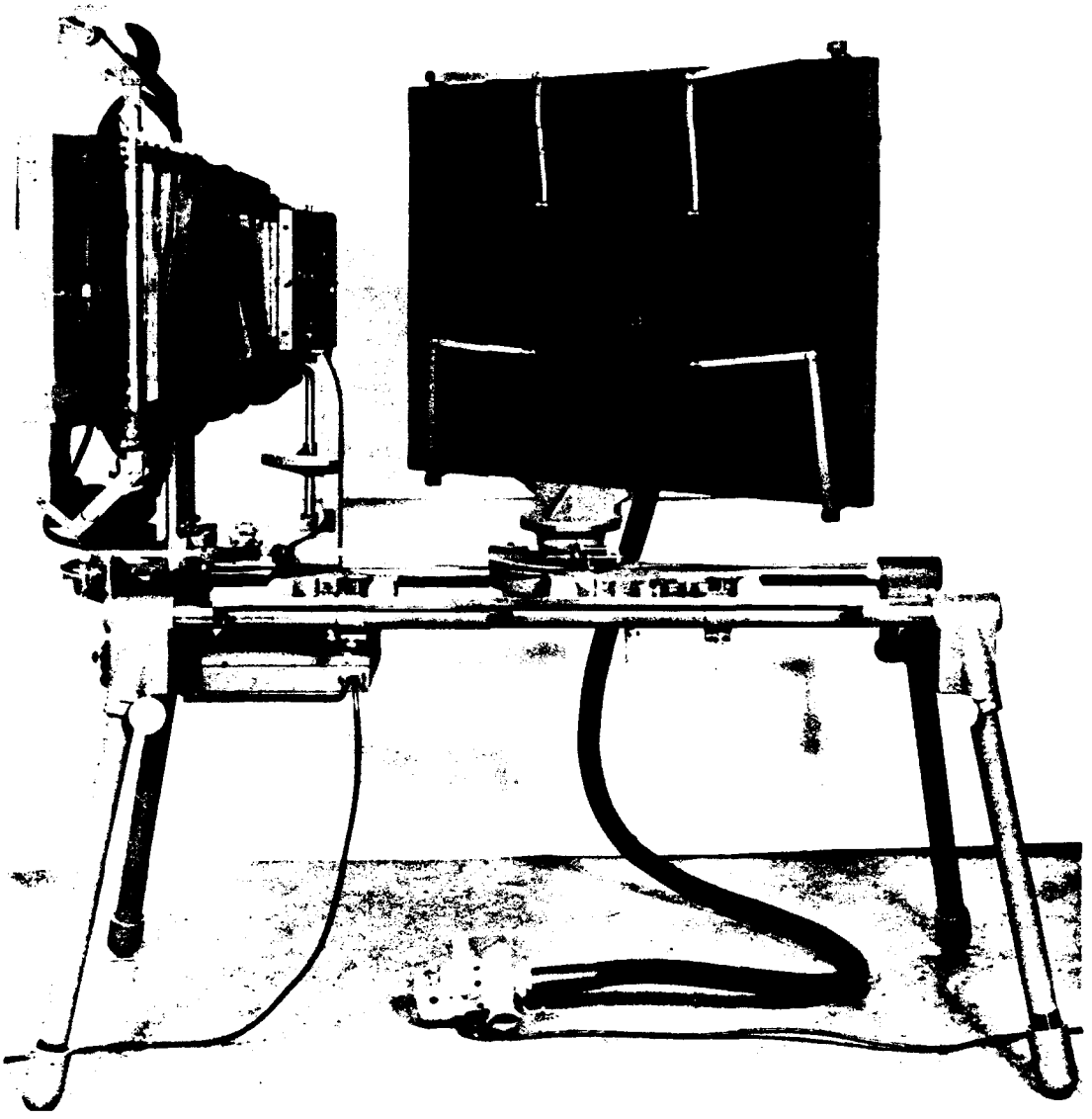

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Fig. 2. Experimental rectifier constructed by Bausch and Lomb Optical Company.

d. Negative Carriage. The negative carriage, for the most part of cast aluminum construction, has provision for rotating the negative about a vertical axis which is positioned at a distance 1/3 the thickness of the stage glass in front of the negative plane. The negative plane is canted manually for large motions, but for accurate settings a clamp and tangent screw is provided. The swing of the negative is actuated by a knurled knob that is accessible when the light source is swung away from the negative. Supports provided for mounting standard aerial film spools can be adjusted to center the spools when the negative is being aligned with the fiducial marks on the negative stage. The film is flattened on the stage by a pressure glass hinged to the negative carriage.

e. Illumination. The light box is fabricated of aluminum alloy, and is hinged to the negative carriage so that it is canted with the negative carriage but is not free to swing in its own plane. The area of illumination has been made sufficiently large to illuminate the diagonal of a 9- by 9-inch negative as the film is swung through 360° in its own plane. The light source is a bank of sixteen, 15-watt 18-inch fluorescent tubes placed behind a ground glass diffuser. A toggle switch is provided for individual control of each lamp and there is also a master switch for control of the entire bank. The activators for the lamps are all contained in a metal box mounted on the base of the rectifier, and the starters are mounted in the light box.

f. Lenses. Three interchangeable f:6.3, projecting metrogon lenses of 4½-, 5½-, and 7-inch focal lengths are supplied with this instrument. The 4½-inch lens is intended for use in rectifying the high oblique photography of the tri-metrogon assembly, and the 7-inch lens is for use in rectifying photography of low tilt. The 5½-inch lens was an experimental model and was used to determine whether it might be satisfactory for all rectifications required of the instrument in lieu of the 4½- and 7-inch lenses. All lenses are mounted in Betax shutters.

g. Special Scaling Device. The Bausch and Lomb rectifier is equipped with a special scaling device for the express purpose of simplifying the calculations necessary for setting (Fig. 3). The short bar is rigidly connected to the shaft supporting the lens and is always perpendicular to the optical axis of the lens. The long bar is rigidly connected to a bracket which pivots at the center of rotation of the negative. This bracket also carries the verniers for two graduated circles at the negative end of the instrument. One of these circles is fixed in position with respect to the base of the rectifier, and the other circle rotates with the negative. Thus, when the long bar is rotated about the center of rotation of the negative, the angle of rotation of the bar can be read on the fixed circle, and the angle of cant of the negative,

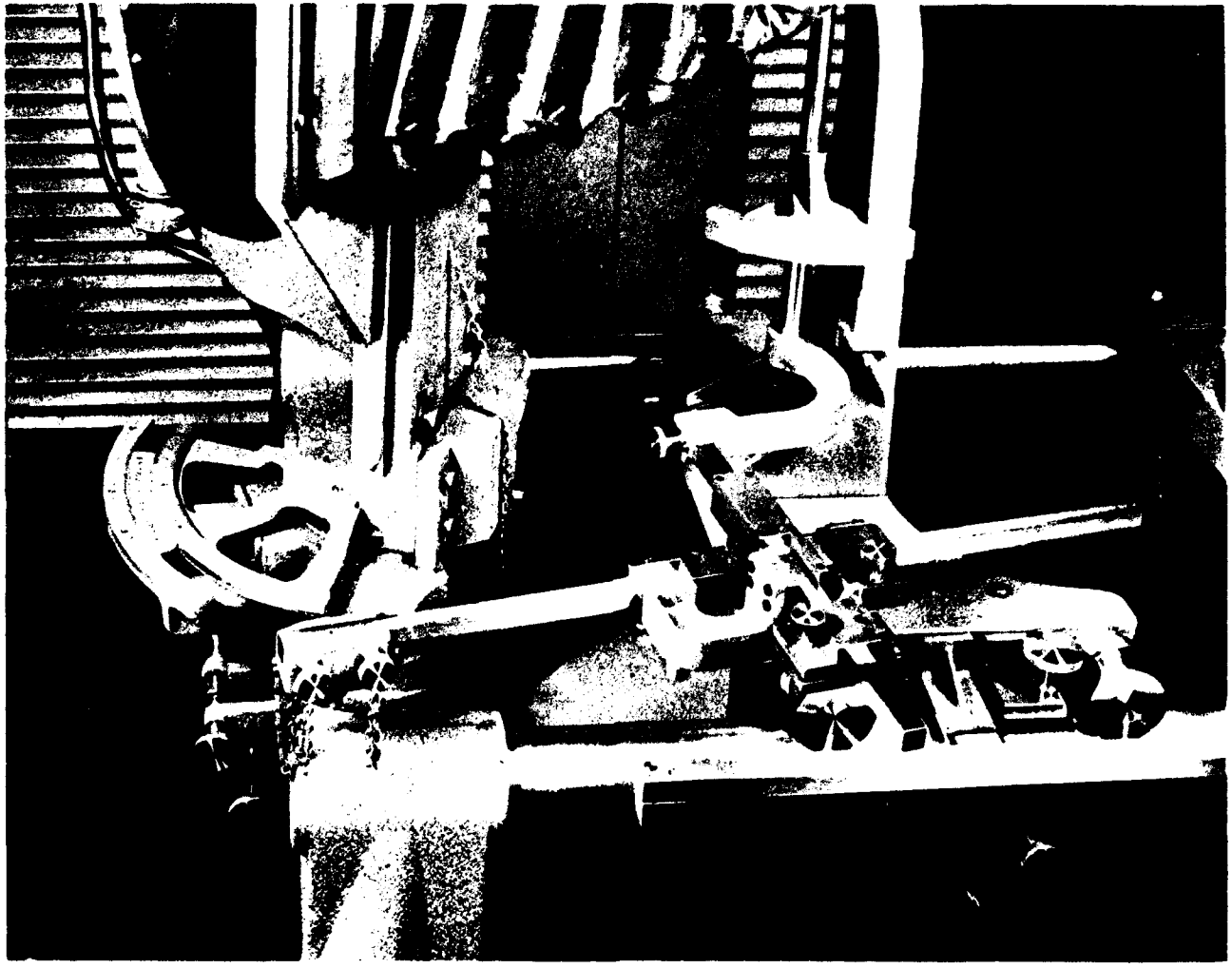

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Fig. 3. Special scaling device constructed by Bausch and Lomb Optical Company.

with respect to the long bar, can be read on the rotating circle. Where the two bars intersect, there is a pin-connected hinge which may be slid along the two bars and may be locked so that the two bars are perpendicular. This hinge device carries verniers, suitable clamps, and slow motion screws for settings along the two bars. In operation, the hinge lock is released, and predetermined distances are set on the two bars; then, the lens carriage is positioned along the bed at the point where the two bars may be locked in a perpendicular position. This automatically positions the lens along the bed and at the same time cants the lens; also, the movable vernier at the negative is positioned in such a manner that the angle of cant of the negative may be determined with respect to the base reference line, instead of referencing it to the optical axis.

Setting the special scaling device requires the computation of two angles and two distances. Values obtained from the scaling device together with the precomputed angles and distances are used as the basis for three additional computations required for the complete setting of the instrument.

8. Deficiencies of Pilot Model Rectifiers. Summarized below are the principal deficiencies noted in the engineering tests of both pilot model rectifiers, together with some observations on the design and performance of each instrument. The engineering tests included tests for: lens distortion and resolution; accuracy of rectification; exposure time; operational and performance characteristics; and accuracy of auxiliary scaling device on the Bausch and Lomb model.

a. Aero Service Corporation Rectifier.

(1) The blackout provisions of the light source were found to be unsatisfactory because of light leaks around the box, and because of the flimsy construction of the curtain shutter.

(2) Precision settings of the scales were difficult to make because of backlash in the gears; also, accurate reading of the easel scale was impossible when the easel was set at zero tilt because the viewing space was blocked-off.

(3) No provision was made for locking the settings on the various scales.

(4) Orientation of film on the stage glass was difficult because of a cramped condition existing around the negative stage.

(5) The mercury light source required a 4-minute warm-up period; in operation, the excessive heat radiation

required forced draft ventilation; and the lack of control of the lights affected the uniformity of the prints.

(6) The easel was thicker and heavier than necessary.

(7) The vacuum pump was larger and heavier and of greater capacity, than was required.

(8) The Baker Hypergon lens of the Aero Service Corporation model did not produce as sharp a print as the projecting metrogon lens of the Bausch and Lomb model when used to rectify photography of high tilts.

b. Bausch and Lomb Optical Company Rectifier.

(1) The frame of the instrument was not sufficiently rigid, and the translation of the lens and easel caused deflection of the tubes.

(2) There were several light leaks around the light blackout shield that could not be adequately blocked.

(3) No safelights were provided on the scales or verniers, necessitating the covering of all photographic emulsions and the turning on of overhead lights to set the scales for each exposure.

(4) Illumination of the fiducial marks was such that all four fiducial marks could not be seen from a single eye position.

(5) Precise rectifier settings could not be obtained from the special scaling device; nor did it simplify the calculation procedure.

(6) The experimental 5½-inch focal length lens did not produce rectified high oblique prints that were as sharp as those produced with the 4½-inch focal length lens.

(7) The projecting metrogon lenses produced sharper prints than did the lenses supplied with the Aero Service model.

(8) More uniform prints were obtained with the fluorescent light source of the Bausch and Lomb model than with the mercury vapor light source of the Aero Service model, as the illumination was easier to control.

(9) The two packing chests were larger and heavier than required.

9. Modification of Bausch and Lomb Rectifier. While both instruments conformed in general to the approved military characteristics for this development, neither was entirely suitable for its intended purpose. The tests indicated that the Bausch and Lomb model was the more desirable of the two, and it was believed that with some modifications to eliminate the deficiencies stated in par. 8, it would be entirely adequate. To accomplish these modifications, the required changes were used as the basis for negotiating a Purchase Order with Fred P. Willcox of Bethesda, Md. As the modifications progressed, it became evident that in order to make some of the changes, the contractor was obliged to rebuild completely certain sub-assemblies. Thus, it was found that instead of modifying the instrument, the original was used merely for the supply of parts in rebuilding. As a result of this rebuilding, the design of the instrument was improved considerably: the center of gravity was lowered, the weight was reduced, and a three-leg support suitable for truck mounting was provided.

10. Description of Modified Bausch and Lomb Rectifier. Fig. 4 shows the modified Bausch and Lomb rectifier as delivered to the ERDL in March 1948. The general design is clean and simple, and the instrument has been constructed almost entirely of light metal alloys; the total weight has been reduced to 310 pounds. The size of the instrument has been reduced to a minimum, so that when assembled for operation, it requires a floor space of only 5 by 3½ feet, exclusive of operator space; the height has been reduced to 6 feet to permit truck mounting. The special scaling device has been eliminated, and scales for the angular motions have been placed in positions so that they can be read more conveniently; in addition, the scales have been equipped with locks and tangent screws for precise setting. Ruby lamps (safelights) have been placed on all scales to permit settings to be made on the instrument while photographic paper is in place on the easel. Two compact chests for packing and transporting the instrument have been designed and built by the ERDL. A detailed description of the components of the rectifier follows:

a. Base. The base is a rigid frame fabricated from 4-inch, structural aluminum alloy channels, and it is supported on adjustable tripod legs in order to minimize the transmission or torsional stresses to the frame when the rectifier is mounted in a truck body. Foot pads are provided for rigid bolting of the legs to the floor of the truck. The ways, or longitudinal tracks on which the lens and easel carriages travel, are half rounds, ground from stainless steel stock. Two level bubbles mounted at right angles to each other on the base, are provided to indicate the level of the ways.

b. Easel and Easel Carriage. The easel has not been changed from the original instrument since the size of the original

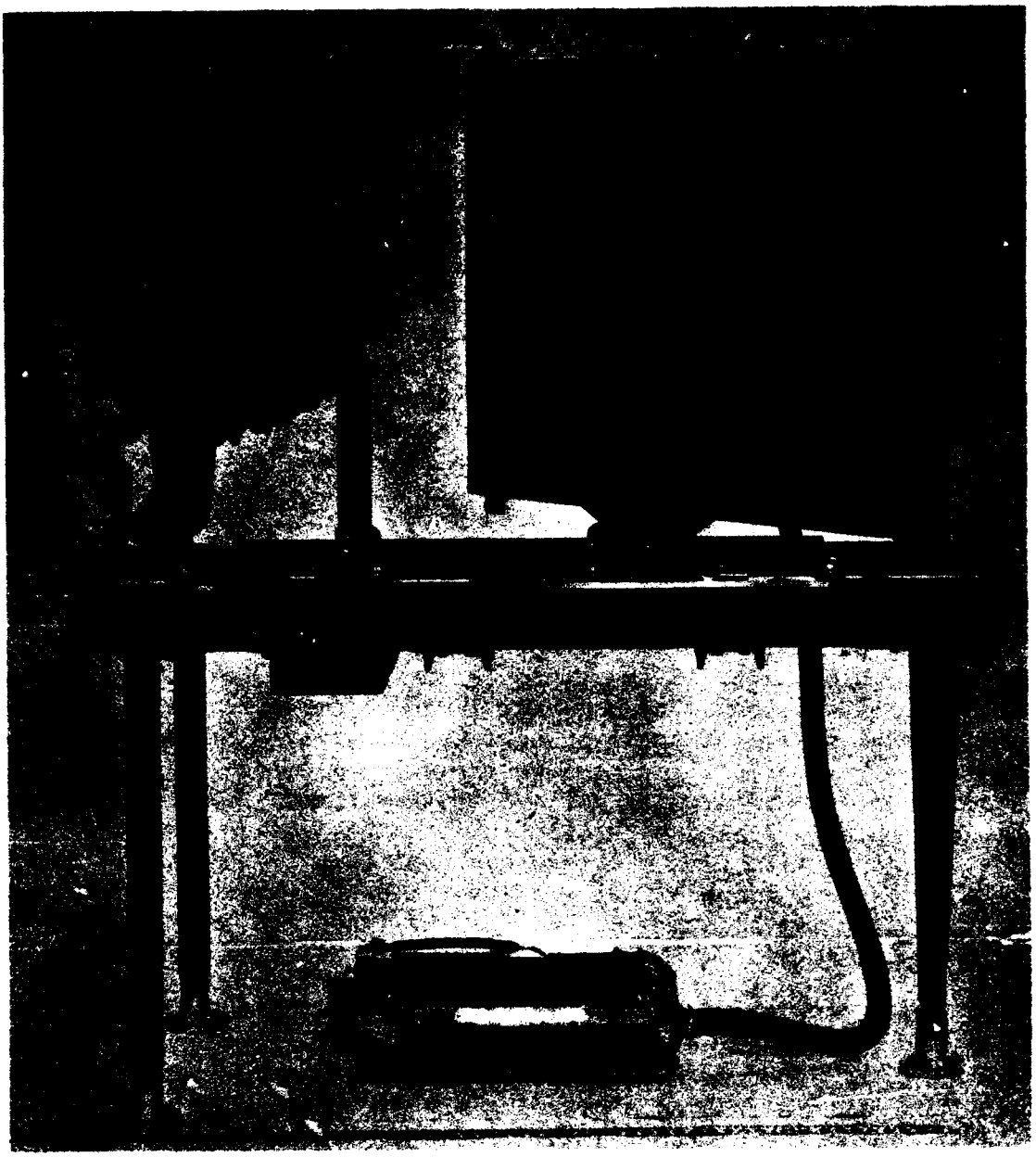

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Fig. 4. Side view of modified Bausch and Lomb rectifier.

design is required to accommodate the maximum magnification; however, the easel carriage has been modified by underslinging it with respect to the ways in order to lower the center of gravity. The easel carriage is supported on the ways by rollers 7/8 inch in diameter; two on one side are "V" type, and the single roller on the other is plane faced. The rollers were designed with a unique adjustment feature that permits .050-inch lateral, and .020-inch vertical adjustments. Vacuum is supplied the easel frame by a standard household vacuum cleaner.[1]

c. Lens Carriage. The lens carriage now consists of a structural aluminum tube 2¼ inches in diameter (which supports the lens), and a fabricated, structural aluminum framework, the center of gravity of which has been lowered in a manner similar to that of the easel carriage. The lens carriage has been further stabilized by separation of the support rollers so that the three point contact approximates an equilateral triangle. To insure against any overturning moment of the lens carriage, lock bearings have been provided under the rollers. These bearings are mounted on spring-loaded pivot arms so that they may be retracted for disassembly of the instrument.

d. Negative Carriage. The negative carriage consists of a fabricated, structural aluminum framework positioned on its vertical bearing by means of alignment pins, and locked in place by three cap screws. The negative stage glass holder is mounted on bearings which allow it to rotate through a full 360° of arc; control of this motion is by hand for large adjustments, and by clamp and tangent screw for small precise adjustments. The design is such that film may be easily placed on the stage glass or removed from it without dismantling any part of the instrument. A ruby glow lamp has been placed behind each fiducial mark to provide for ease in centering the film from a single eye position. Each lamp is mounted on a pivot arm, and all four are interconnected by means of pulleys so that they may be swung out of the way (when not in use) by a lever located at the rear of the negative frame.

e. Illumination. The illumination unit has been completely redesigned and now consists of a light-tight, sheet aluminum box containing fourteen, 8-watt, 12-inch fluorescent tubes spaced on 7/8-inch centers, behind a ground glass diffuser. The activators for the lamps are all contained in a metal box mounted on the base of the instrument, while the starters are situated at the rear of the light box directly behind the tubes. A toggle switch is provided

1. A standard household vacuum cleaner provides adequate pressure, is cheap and easy to obtain, and can be supplied with attachments for cleaning dust and dirt from the bearings and other restricted parts of the equipment.

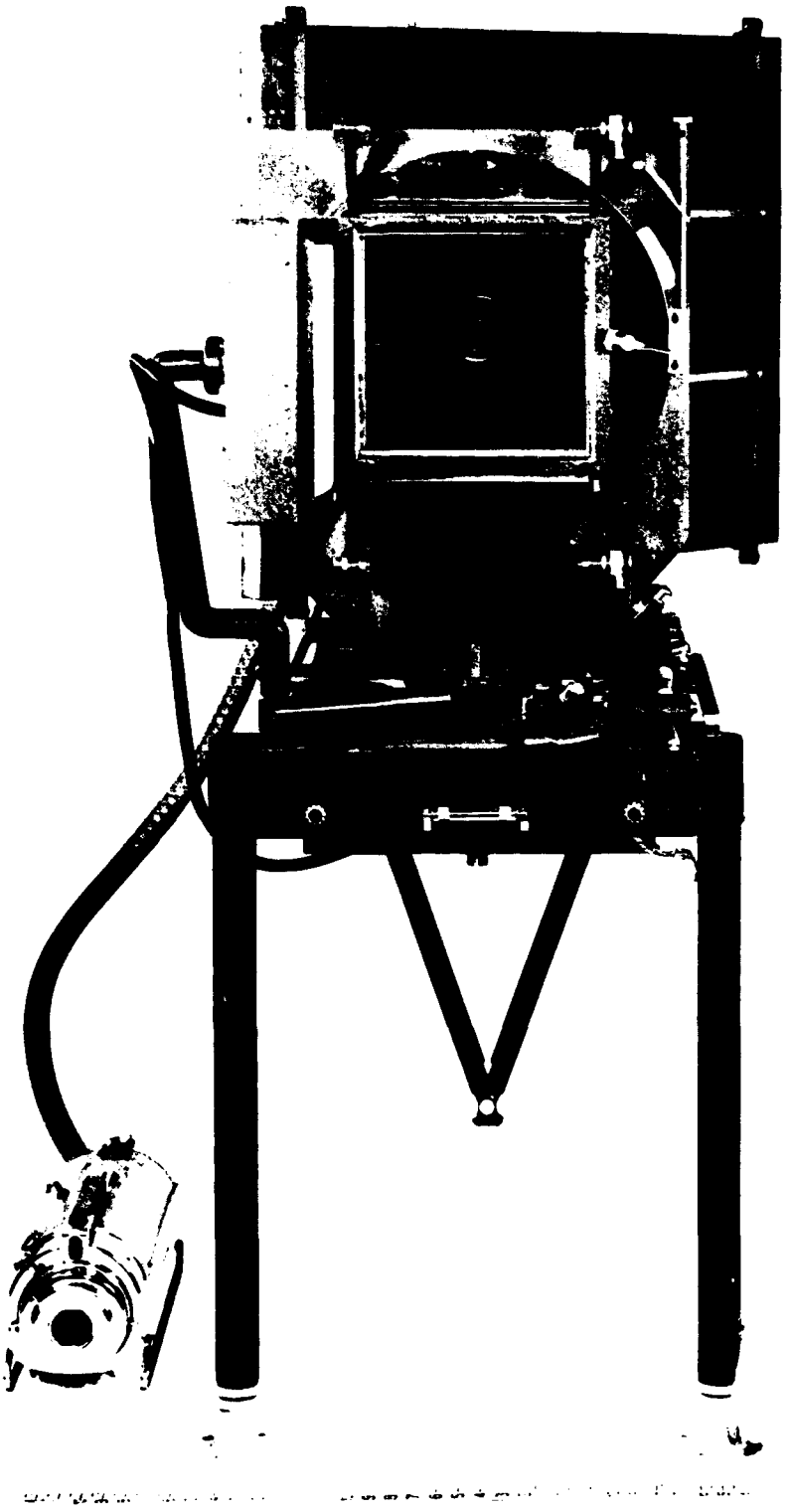

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Fig. 5. Light box mounting and negative stage assembly, modified Bausch and Lomb rectifier.

for individual control of each lamp so that the illumination reaching the easel can be balanced over the entire area of projection. There is also a master switch for control of the whole bank. The light box is mounted by a novel arrangement which allows it to revolve, and fit snugly into place behind the film plane regardless of the cant or swing of the film, thus reducing light leaks to a minimum. The design of this mechanism is such that the tubular arm supporting the light box is supported on a vertical axle rigidly connected to the vertical axis of rotation of the negative carriage (Fig. 5). This allows the light box to be canted with the negative assembly, and also permits the light box to be revolved away from the negative assembly as shown in the figure. In addition, the bearing-type connection between the light box and the tubular arm permits rotation of the light box in its own plane so that accommodation is made for any swing of the negative.

f. Lenses. The 4½- and 7-inch focal length, f:6.3 projecting metrogon lenses previously described are used with the modified instrument. A Wratten gelatin filter has been supplied which may be clipped to the lens, if desired, for use in orienting sensitized paper to the projected image.

11. Assembly and Adjustment. Fig. 6 shows the modified Bausch and Lomb instrument broken down into its component parts. To assemble, the legs are first attached to the frame, the negative carriage is positioned on its alignment studs, the lamp box is secured to its mount, the lens carriage is fitted to the horizontal tracks, the easel and easel carriages are assembled and placed on the tracks, the vacuum hose is interconnected between the easel and vacuum pump, and finally, the lens is secured on the lens mount.

Figs 7 and 8 show how the instrument is placed in chests for shipment. Chest No. 1 occupies 24 cubic feet, weights 340 pounds when fully loaded, and contains the legs, the frame, the easel, and the vacuum pump. Chest No. 2 occupies 14.1 cubic feet, weighs 250 pounds fully loaded, and contains the remainder of the superstructure including the lamp housing, negative carriage, lens carriage, easel carriage, projection lenses, and spare parts.

For truck mounting, the base of the instrument is bolted to the floor of the truck, and chest No. 2 is also bolted to the floor of the truck beneath the base (Fig. 9). For transport in the van, the light source, negative carriage, lens, and lens carriage are removed from the base and placed in the spaces provided in Chest No. 2 (Fig. 10). The easel is also removed from the base and mounted on the floor of the van. This disassembly can be accomplished in about 5 minutes by two men.

Adjustment of the instrument, normally completed in the factory, consists of shifting the component parts of the rectifier

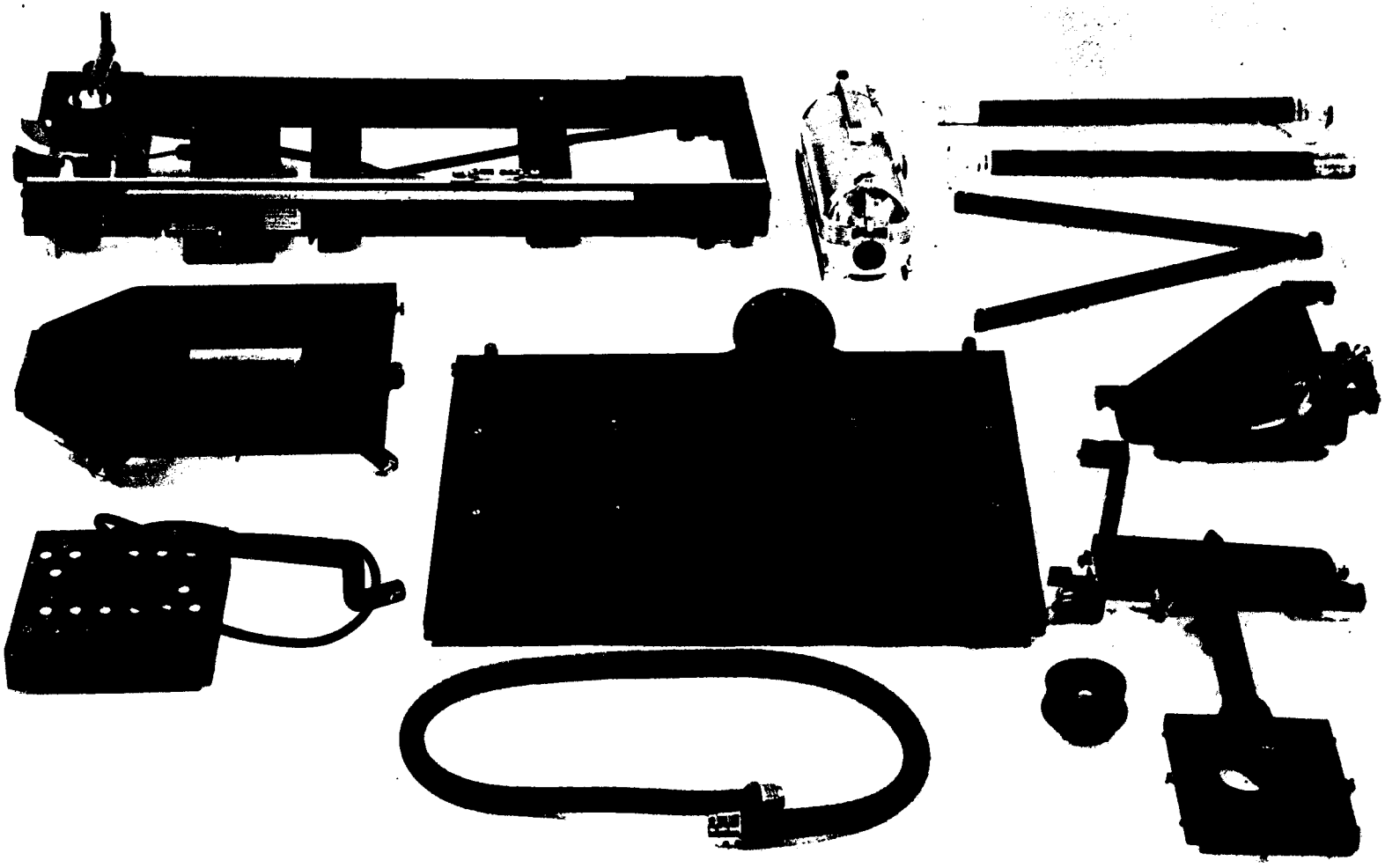

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Fig. 6. Component parts of modified Bausch and Lomb rectifier.

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Fig. 7. Chest No. 1 packed with contents of modified Bausch and Lomb rectifier.

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Fig. 8. Chest No. 2 packed with contents of modified Bausch and Lomb rectifier.

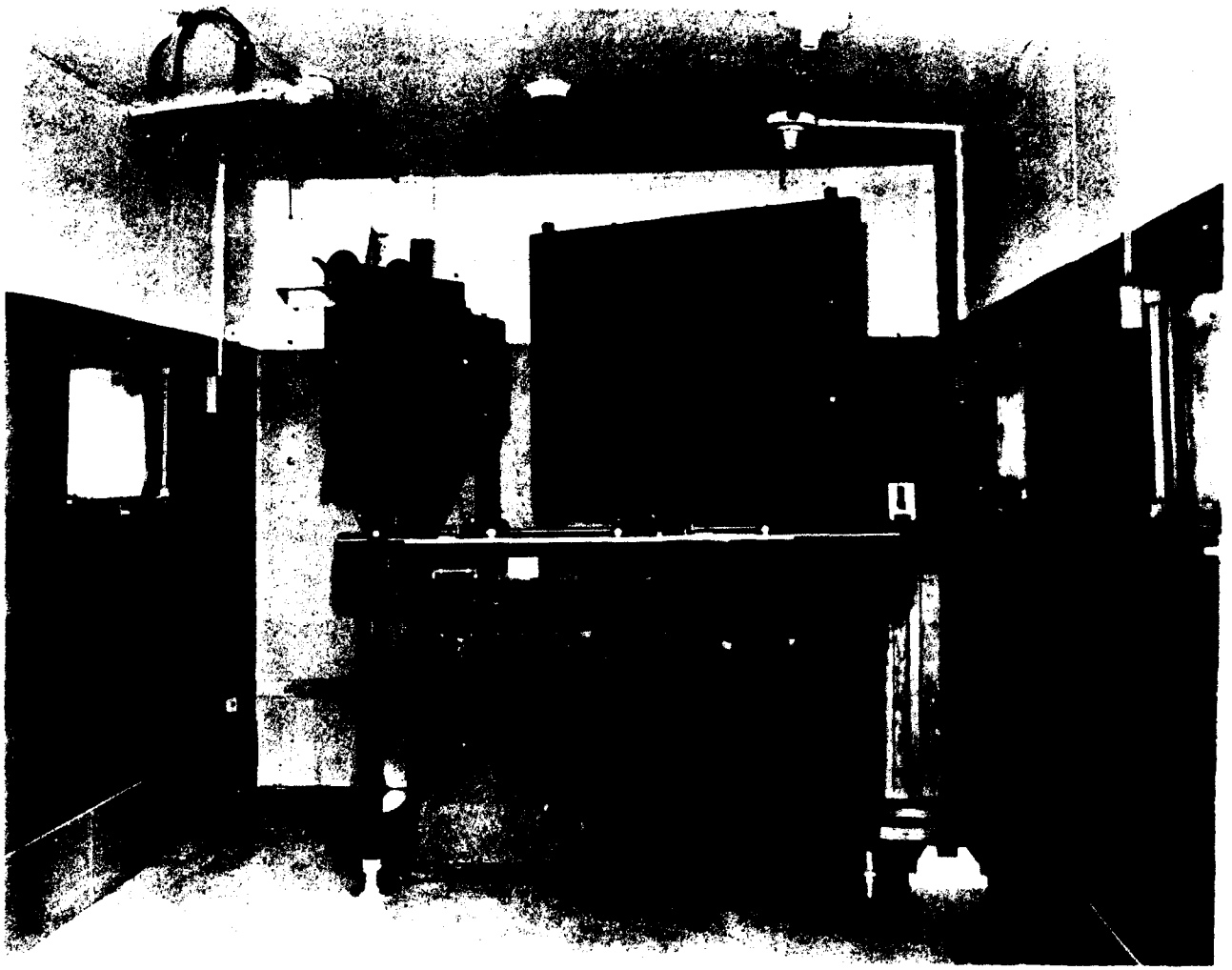

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Fig. 9. Modified Bausch and Lomb rectifier mounted in van-type truck body.

into their true mechanical alignment by means of adjustable bearings to satisfy the following criteria:

a. Alignment of Axes of Rotation. The horizontal and vertical axes of rotation are adjusted so that when the instrument is varied from extreme reduction to extreme magnification with either lens, the projected image of the center of the negative is displaced less than 0.020 inch.

b. Scale of Projection. The negative, lens, and easel planes are adjusted in such a manner that the scale of the projected image of a true grid will be true in all directions to an accuracy of one part in 750.

12. Operation of the Modified Bausch and Lomb Rectifier. Operation of the instrument involves five separate steps, assuming the rectifier settings have been previously calculated.

a. Film Negative Orientation. The film negative, either cut or roll, is oriented to the fiducial marks of the stage glass (emulsion side down), and is secured by locking the pressure glass into place behind it.

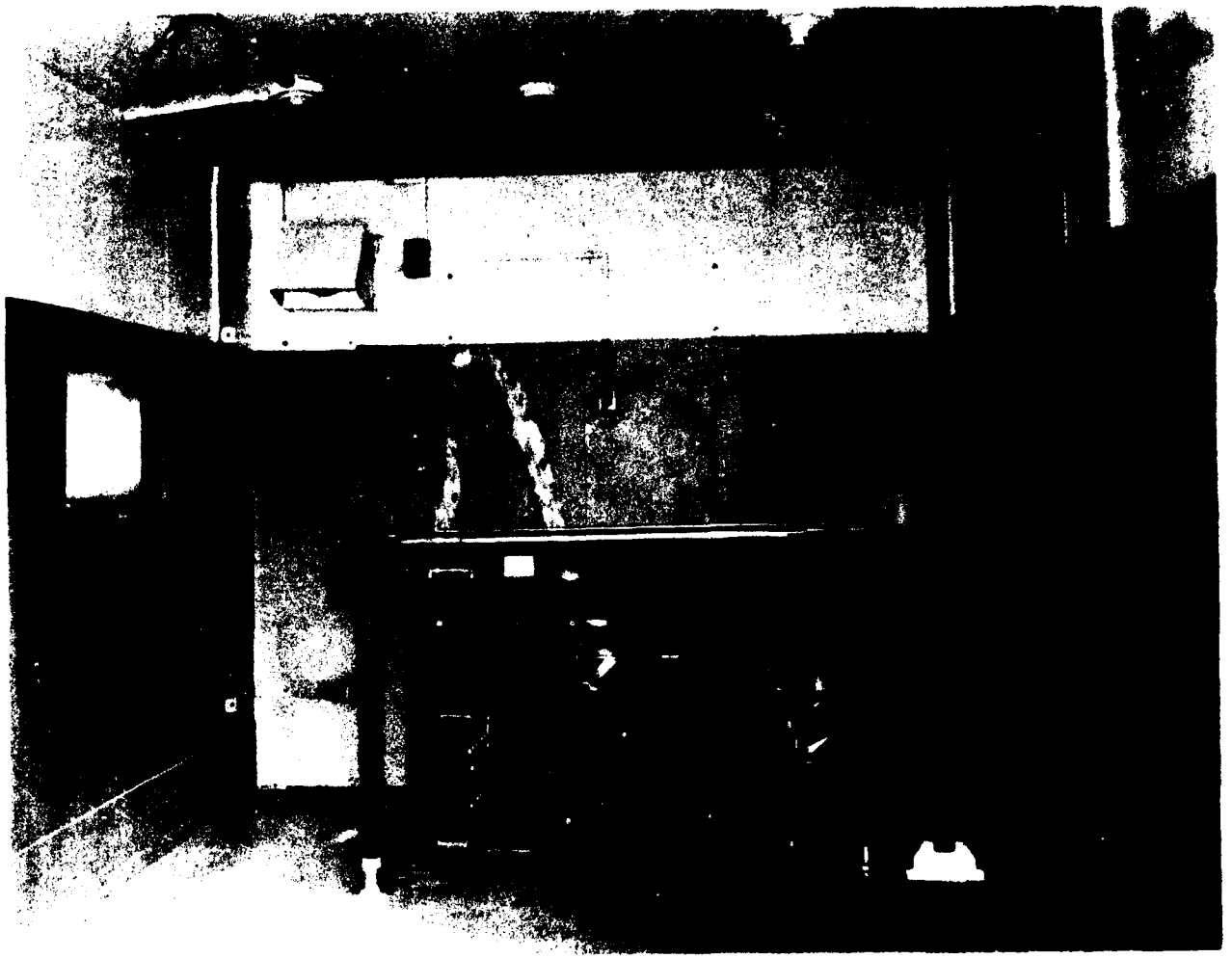
b. Scale Settings. Three angular scales (cant of negative, lens, and easel) and two linear scales (spacing of negative to lens, and lens to easel), must be set for each rectification. It may be necessary to set an additional angular scale (swing) if the negative contains a combination of tip and tilt.

c. Adjustment of Illumination. The projection lights are adjusted by turning off those not required until uniform illumination is obtained on the easel. After the safe filter is placed over the lens, sensitized paper is fitted on the easel in proper orientation, the lens closed, and the filter removed.

d. Exposure. The lens is then stopped-down to the desired opening, and the exposure is made by opening the shutter, such action being accompanied by hand dodging, if required.

e. Print Processing. The exposed print is removed from the easel, developed, fixed, washed, and allowed to dry.

13. Calculation of Settings. For precise rectification and simultaneous sharp focus in any optical rectification apparatus, certain geometric relationships must be set up in the instrument for the relative position and orientation of the negative, projection lens, and easel; these positions and orientations are dependent upon the camera focal length, projection lens focal length, and the tilt of the aerial camera at the instant of exposure. For this



170-1-8

Fig. 10. Modified Bausch and Lomb rectifier mounted in van-type truck body, with superstructure packed for transport.

instrument, it is necessary to calculate the cant of the negative, lens, and easel with respect to the line between the principal point of the negative and the node of the projection lens, and to calculate the spacings between the negative, lens, and easel. These values are then set on the scales and circles provided. Formulae for the calculation of these settings (Fig. 11) are as follows:

$$\text{Sin } t_p = \frac{f}{F} \sin T$$

$$\text{Sin } t_n = \frac{f \sin T}{F M}$$

$$\alpha - \beta = t_p + t_n$$

$$\text{Cot } \frac{(\alpha + \beta)}{2} = \frac{\tan^2 \frac{1}{2}T}{\tan \frac{1}{2} (\alpha - \beta)}$$

$$\alpha = \tfrac{1}{2} (\alpha - \beta) + \tfrac{1}{2} (\alpha + \beta)$$

$$\beta = \tfrac{1}{2} (\alpha + \beta) - \tfrac{1}{2} (\alpha - \beta)$$

$$\gamma = \beta + t_p$$

$$c = f \csc^2 \lambda \csc \gamma$$

$$d = f \sec^2 \lambda \csc \gamma$$

where $\tan^2 \lambda = M \sec T = d/c$

in the above formulae

F = focal length of camera lens
f = focal length of rectifier lens
T = tilt of aerial photograph
M = magnification ratio

In addition to solving the above formulae for setting the instrument, it is necessary to apply a correction to the easel distance for the nodal separation in the projection lens determined by the formula

$$n' = n (\sin \gamma + \cos \gamma \cot \beta)$$

in which n is the nodal separation of the lens.

14. Aids to Calculation of Settings. One of the military characteristics for this development requires that aids to the

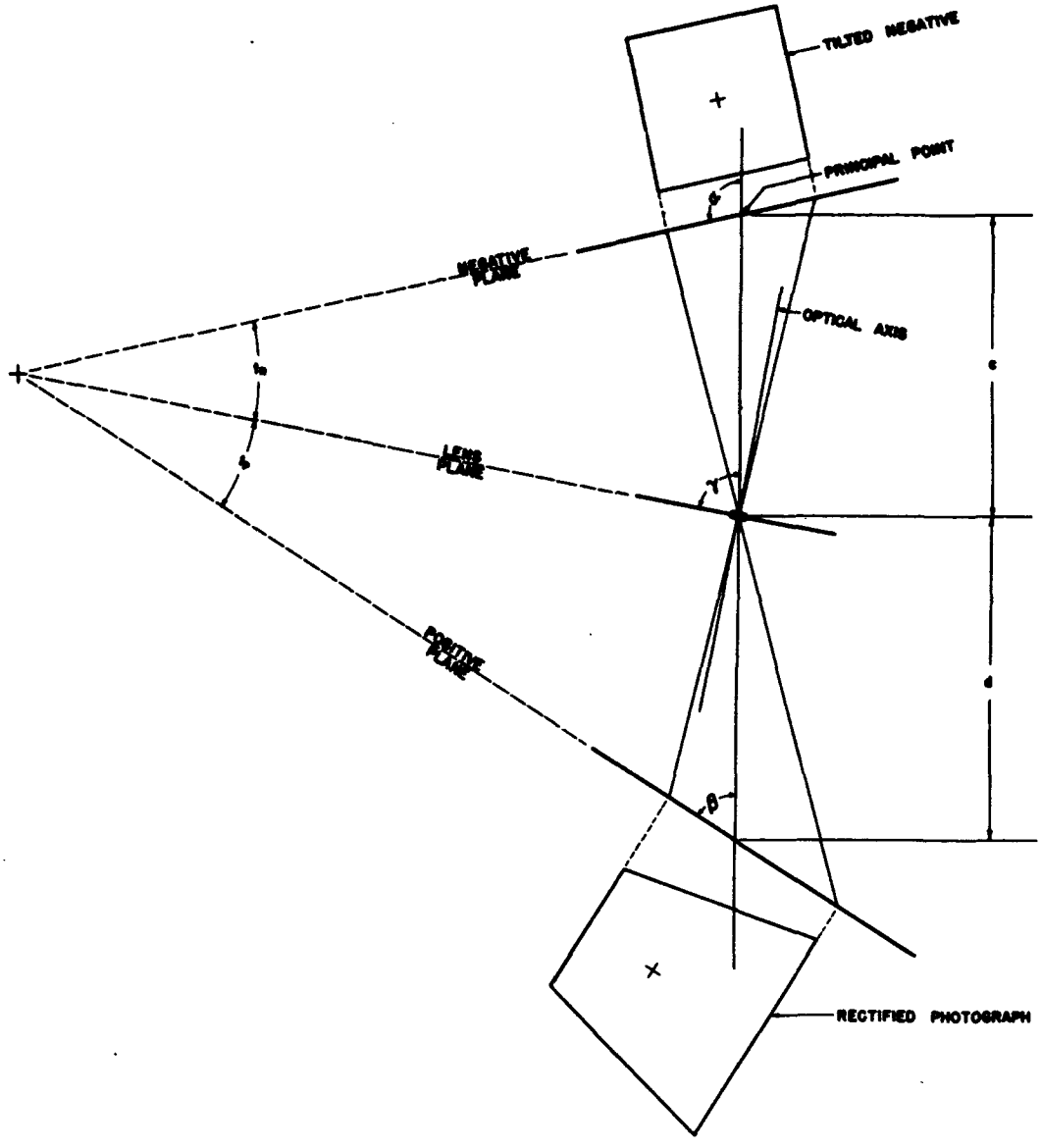


Fig. 11. Diagram of geometrical relations of modified Bausch and Lomb rectifier.

determination of settings such as nomograms, charts, or curves be supplied with the instrument. During the course of this development, both a set of nomograms (Figs. 12 through 19), and a circular slide rule (Fig. 20) were developed. In addition, the possibility of supplying a set of curves for this purpose was investigated.

The complete set of nomograms consists of eight 20- by 22-inch sheets, of which four are the basic charts, and will provide settings for the complete range of rectification, while the remaining four are exaggerated scales of portions of the four basic charts for more accurate values of settings for tri-metrogon photography. Rectifier settings may be determined from the basic nomograms for all tilts from 0° to 90°, for f/F ratios between 0.25 and 2.5, and for isoline magnifications from 0.3 to 3.0.

The circular slide rule consists of a heavy cardboard base 13 inches in diameter, a central circular section 10 inches in diameter printed on thin cardboard stock, and a plastic indicater; the entire unit is held together by means of a plastic center button. Rectifier settings may be determined from the slide rule for all tilts from 5° to 70° and for magnifications between 0.6 and 2.5. Construction of a rule with tilts below 5° is not practical.

Curves can be plotted for each motion of the rectifier by computing limiting values from the formulae, plotting the points, and connecting them by smooth curves. This method is practical only when the focal length of the taking camera, the approximate tilt, and the desired magnification are known prior to construction of the curves; otherwise, an infinite number of curves must be supplied.

Comparison of the nomograms and slide rule indicate that their speeds of operation are about equal, that is, approximately nine complete computations per hour. Accuracies are considerably better with the nomograms than with the slide rule; for tri-metrogon photography, the average angular error is 2.5 minutes and the average linear error, .15 mm; for near vertical photography, the average angular error is 6.7 minutes and the average linear error, 2.3 mm.

Neither the nomograms nor the slide rule will give the desired accuracy where precise, geometrically correct, rectifications are to be made; however, either will give sufficient accuracy for most applications of the instrument and for a rapid determination for checking purposes.

15. Engineering Tests and Results. Descriptions of the engineering tests conducted at the ERDL to determine the conformance of the instrument with the military characteristics and its suitability for service test follow:

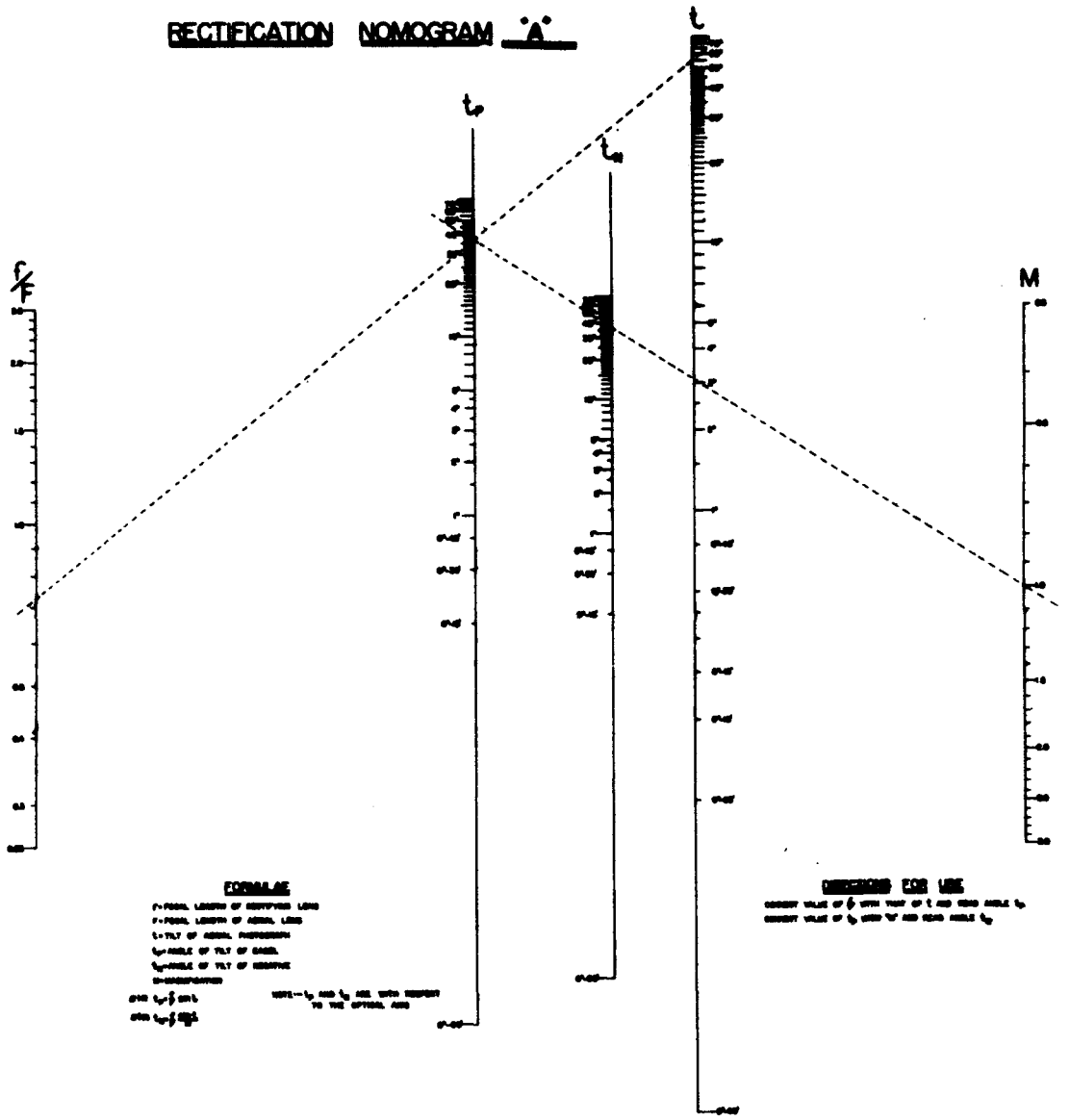


Fig. 12. Nomogram for determination of values of t_p and t_n for settings on modified Bausch and Lomb rectifier.

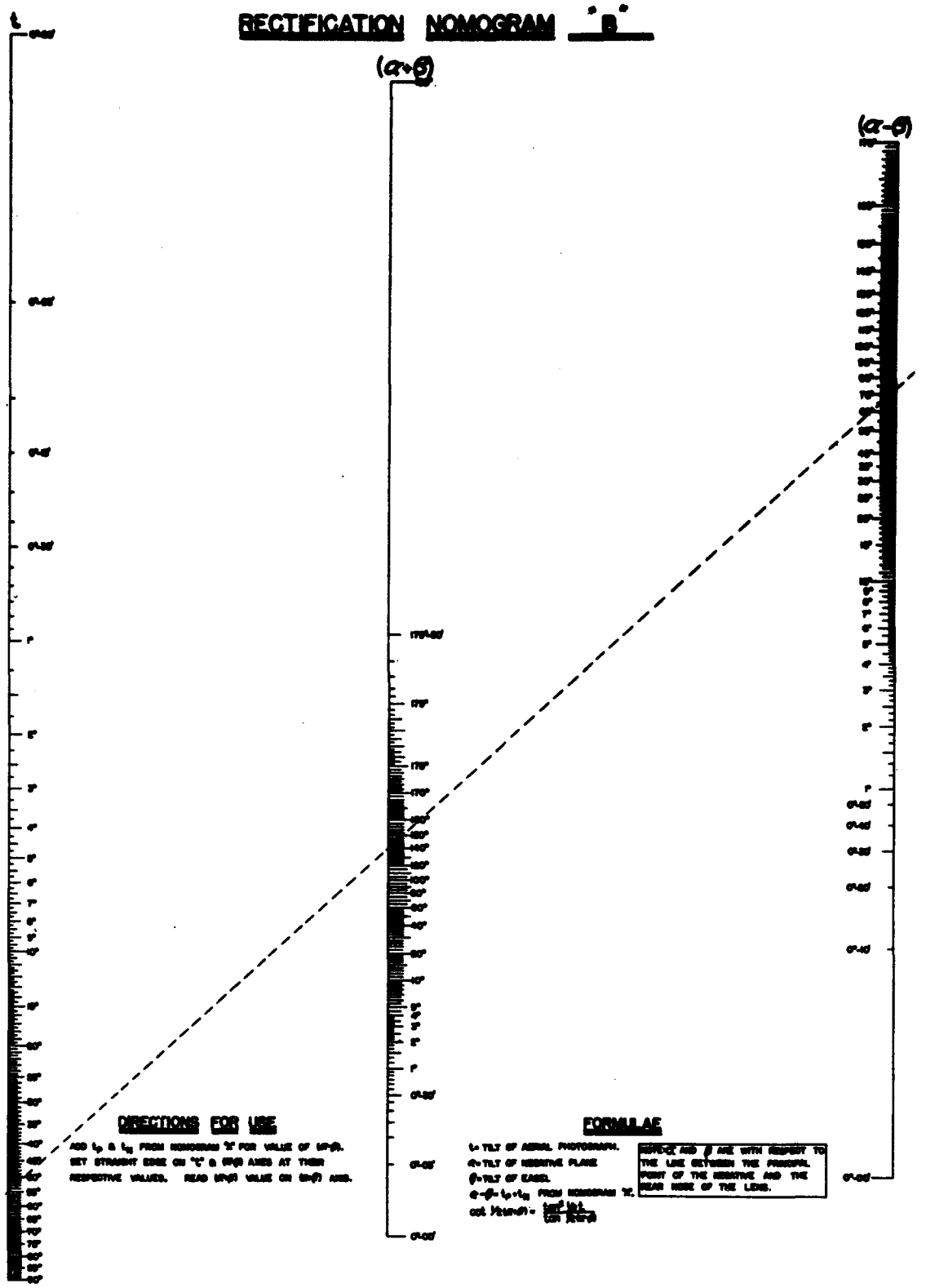


Fig. 13. Nomogram for determination of value of $\alpha + \beta$ for settings on modified Bausch and Lomb rectifier.

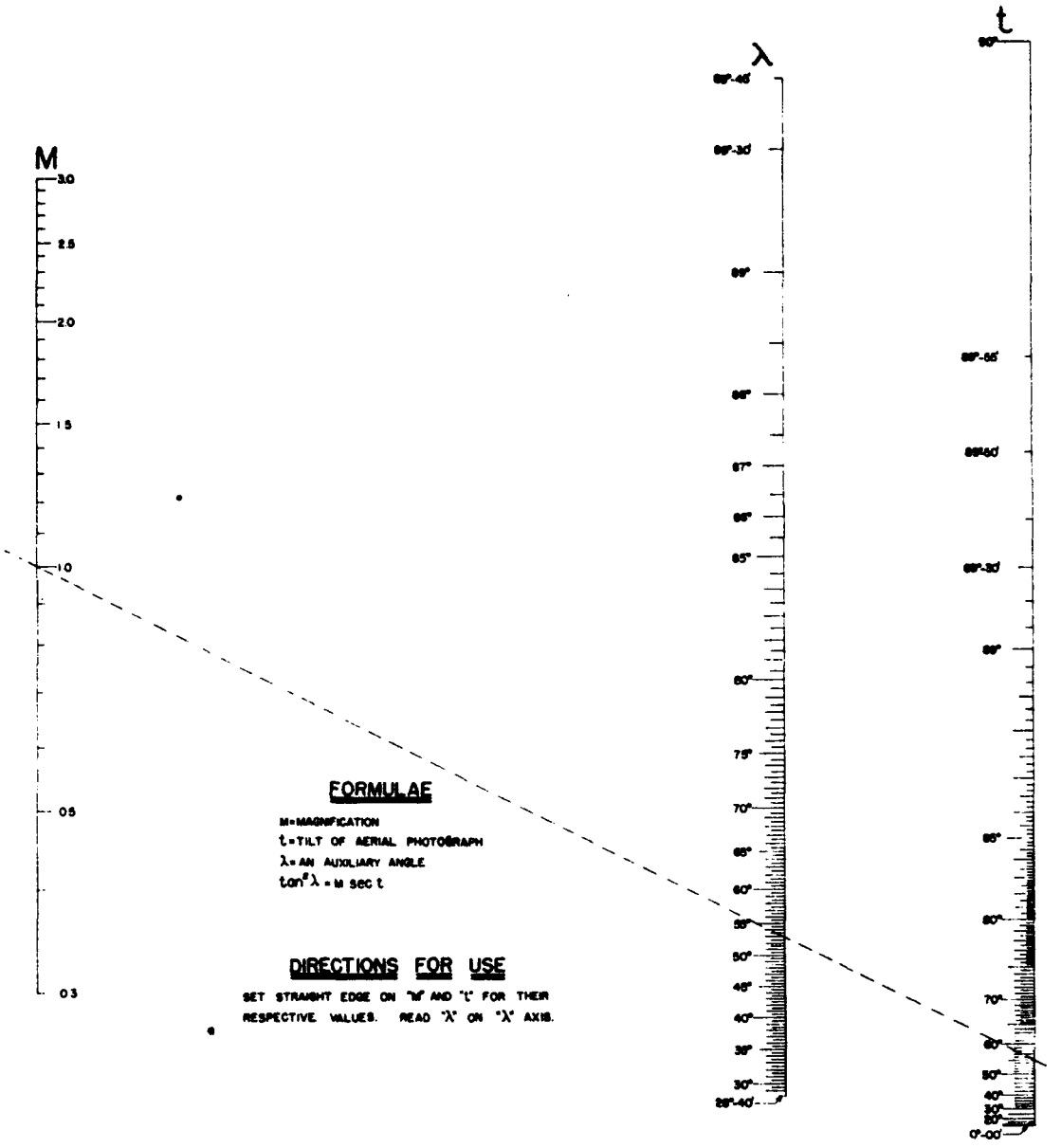


Fig. 14. Nomogram for determination of value of λ for settings on modified Bausch and Lomb rectifier.

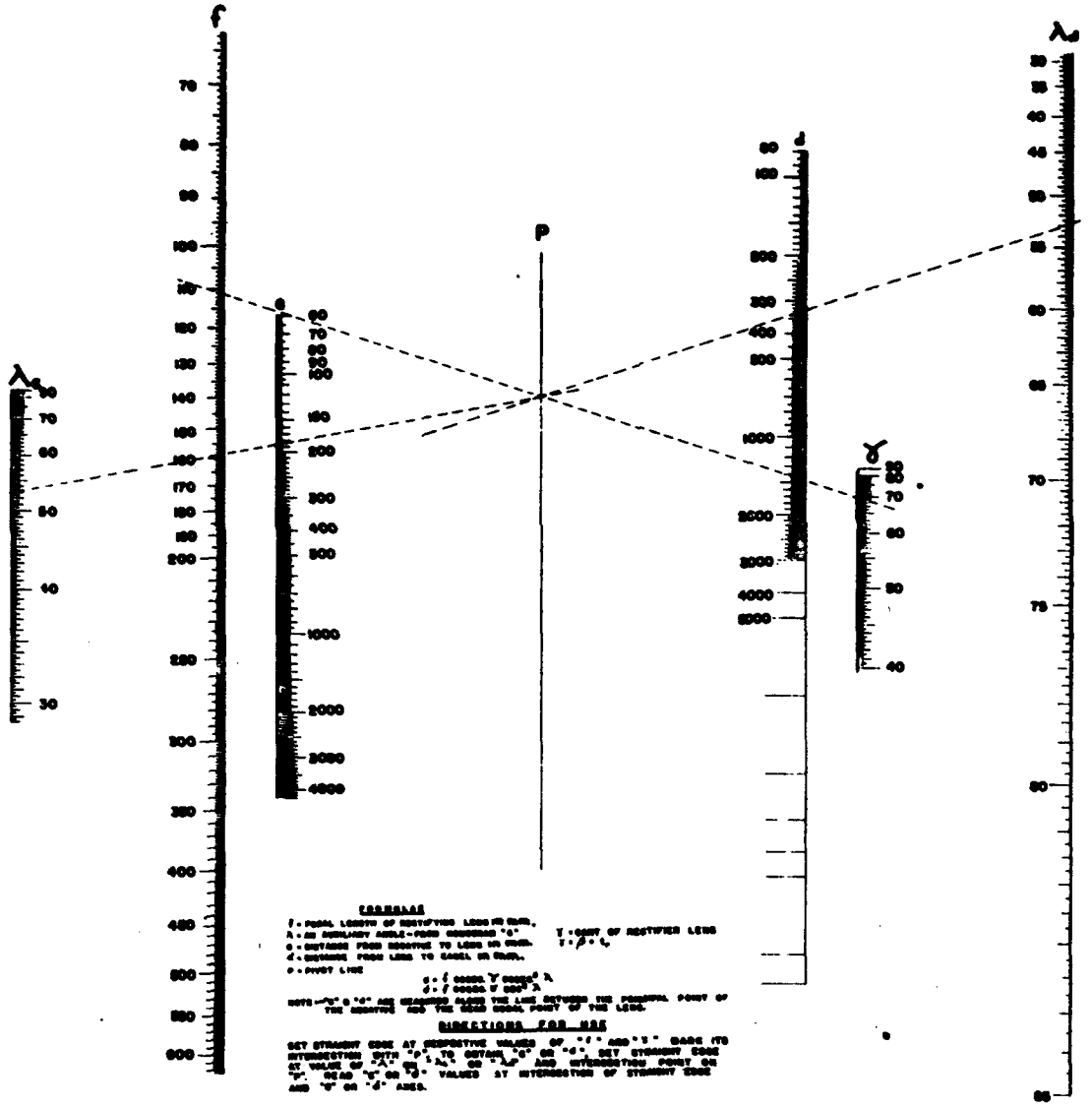


Fig. 15. Nomogram for determination of values of c and d for settings on modified Bausch and Lomb rectifier.

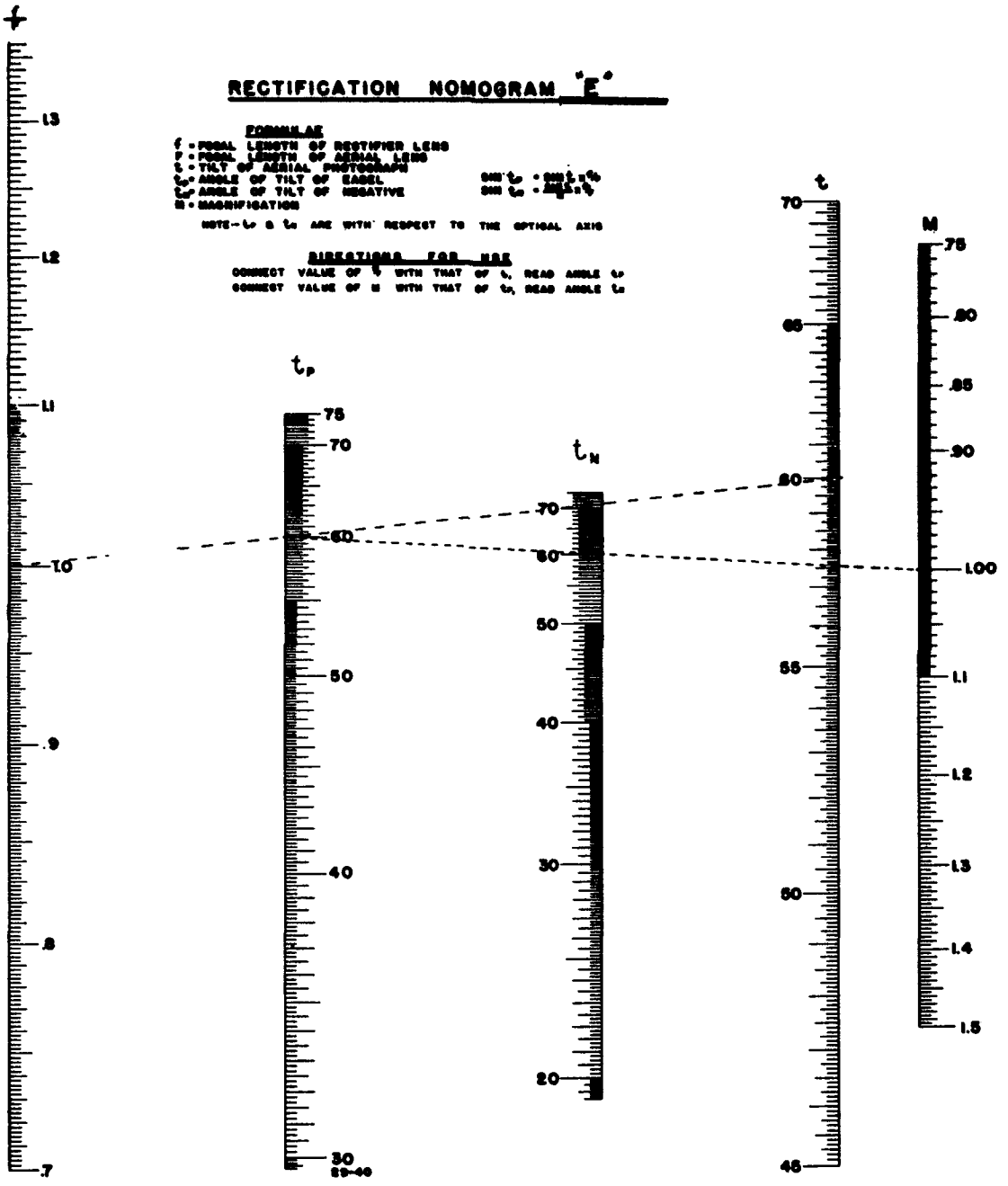


Fig. 16. Nomogram for determination of values of t_p and t_n for high oblique photography to be set on modified Bausch and Lomb rectifier.

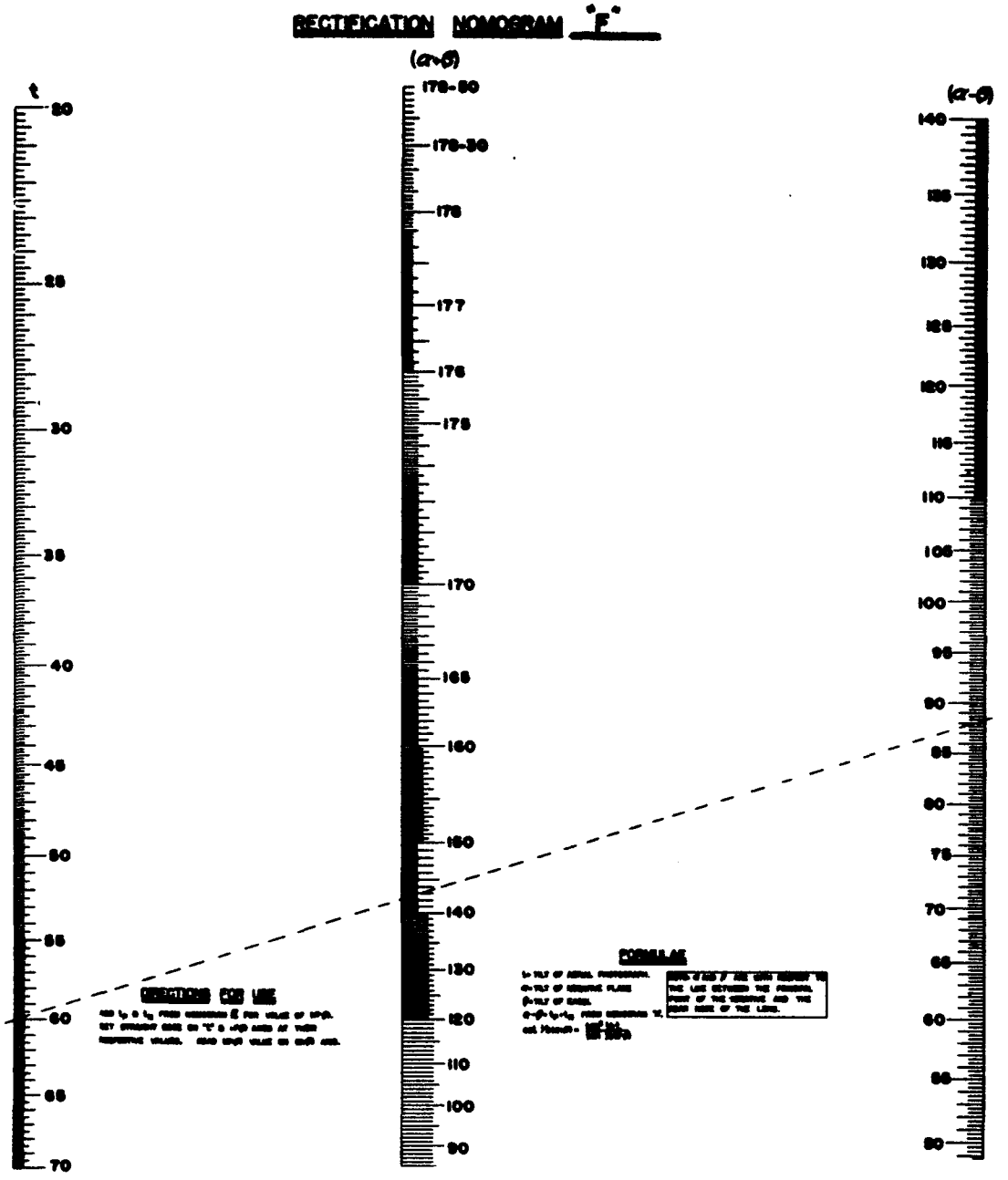


Fig. 17. Nomogram for determination of value of $\alpha + \beta$ for high oblique photography to be set on modified Bausch and Lomb rectifier.

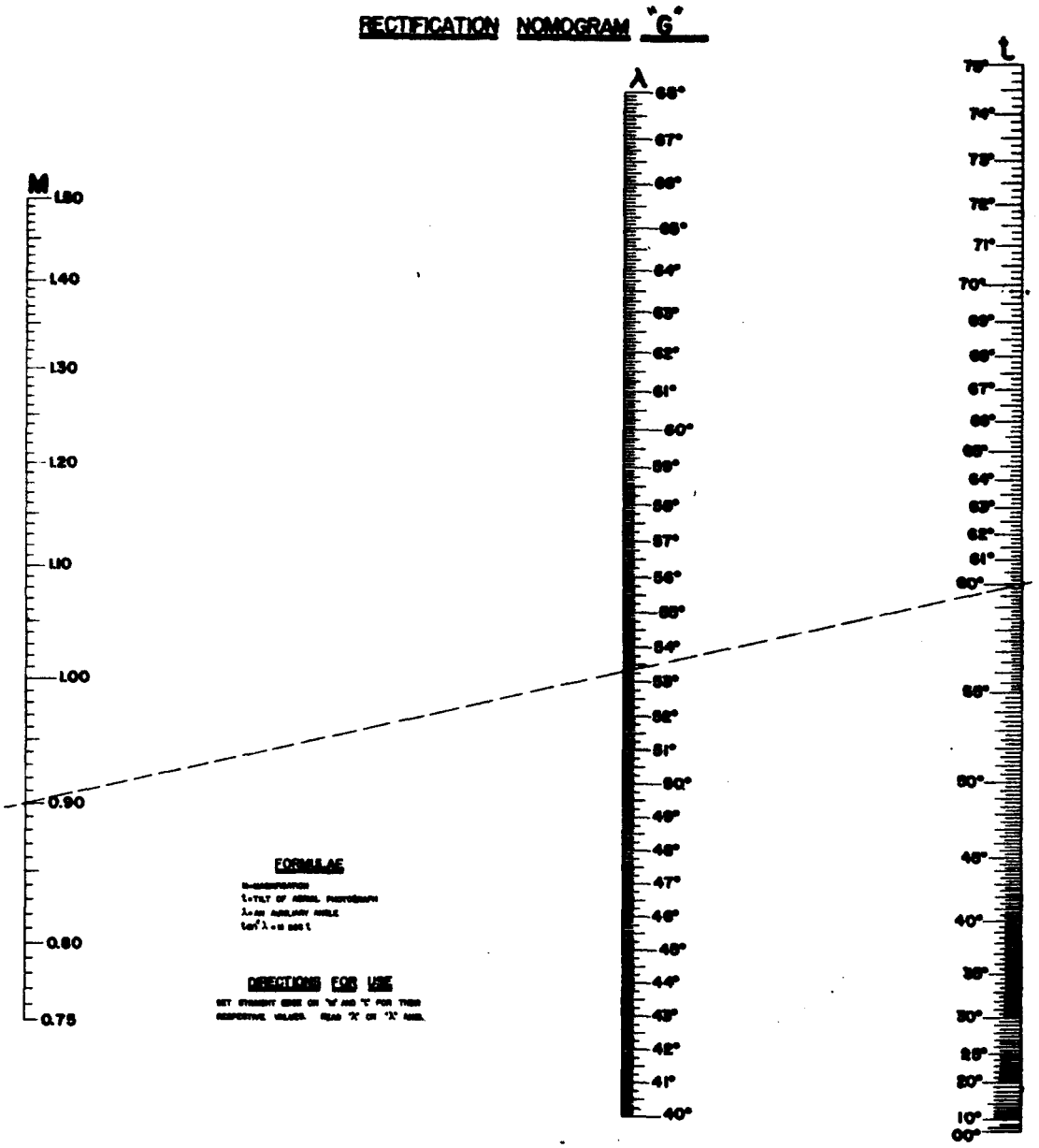


Fig. 18. Nomogram for determination of value of λ for high oblique photography to be set on modified Bausch and Lomb rectifier.

RECTIFICATION NOMOGRAM 'H'

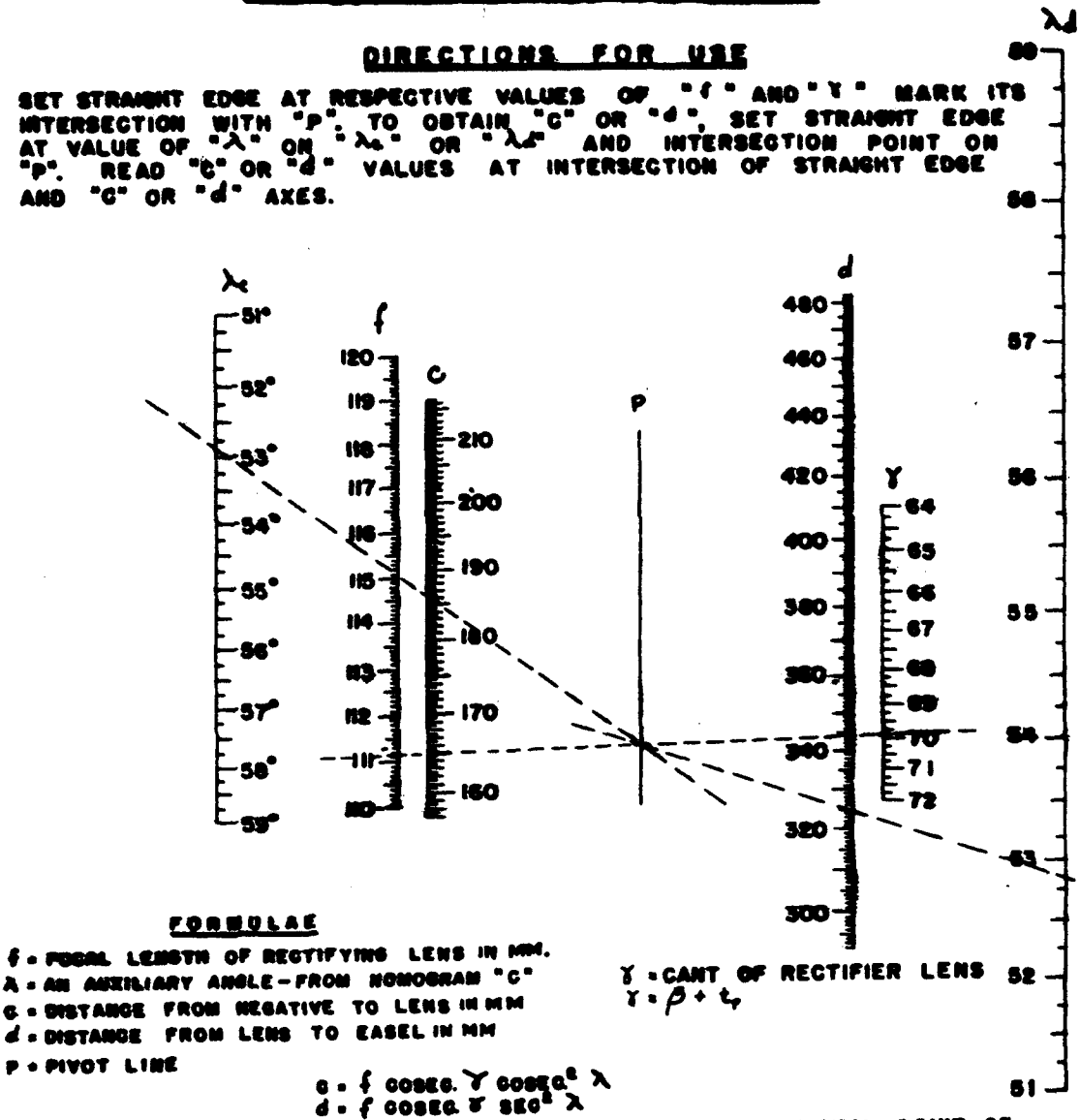


Fig. 19. Nomogram for determination of values of c and d for high oblique photography to be set on modified Bausch and Lomb rectifier.

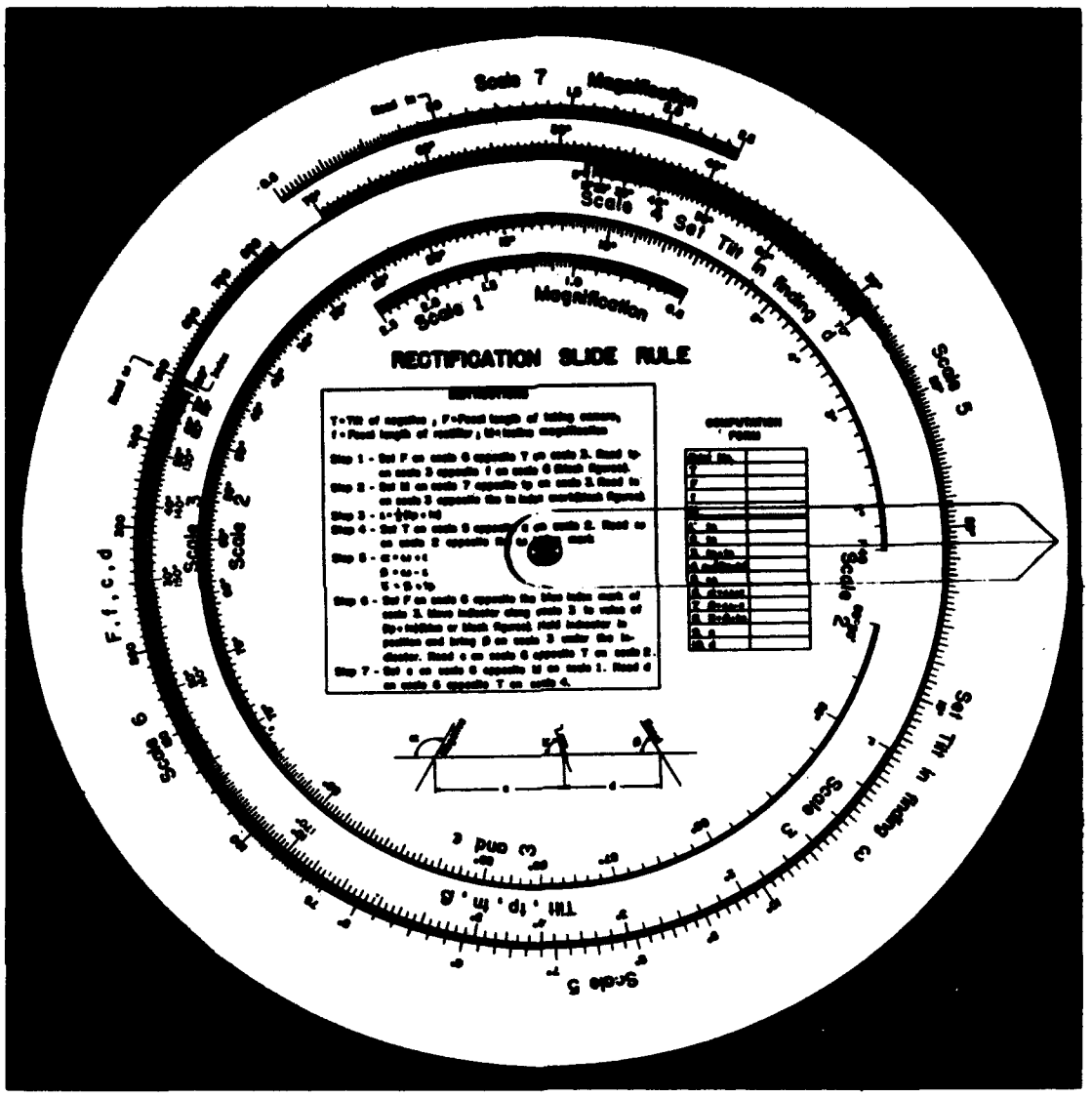


Fig. 20. Slide rule for determination of values for settings on modified Bausch and Lomb rectifier.

a. Performance Characteristics. Routine laboratory procedures were used to check the performance characteristics of the instrument.

(1) Accuracy of 60° Rectification. The rectifier was set up with the calculated scale values for the 4½-inch lens, a true perspective grid drawn at a 60° tilt was oriented on the fiducial marks, and the projected image of the grid was compared to its theoretically correct shape and dimensions at an isoline scale of 1:1. The results of this test are shown in Fig. 21, in which the arrow indicates the direction, and the numeral the amount of error in millimeters. In general, the error introduced by the rectification process will be less than the error introduced by inherent inaccuracies in determining the exact tilt angle.

(2) Lens Distortion. The distortion in the 4½- and 7-inch, focal length lenses is shown in Table I. These distortions were determined by projecting a master scale of known dimensions through the lens and exposing the image on white pigment base acetate for measurement. The distortion is expressed in millimeters at the scale of the projection, positive values indicating that the image is displaced radially outward from the center with respect to its distortion free position. The estimated accuracy of these measurements is ± 0.02 mm.

Table I. Lens Distortion at Two-diameter Magnification

Lens	Distance Out from Center of Positive (mm)					
	0	50	100	150	200	250
4½-inch	0.0	-0.08	-0.13	-0.18	0.00	+0.35
7 -inch	0.0	+0.03	+0.03	-0.01	-0.04	-0.04

(3) Lens Resolution. The resolving power of the 4½- and 7-inch projecting metrogon lenses is shown in Table II for a 2-diameter enlargement. These values were obtained by exposing, on film, resolution targets containing patterns of lines spaced 2, 3, 4, 5, 6, 8, 10, 13, 16, 20, 25, 32, 40, 50, 63, and 80 lines per millimeter. The results indicate the number of lines per millimeter resolved tangentially and radially, in the negative plane, at various angles from the center of the field. The lenses were set at f/11 opening for these tests.

(4) Range of Rectification. The range of rectification of the modified instrument is shown in Fig. 22. In this figure the isoline magnification is plotted against the tilt; the range required by the military characteristics is shown by the cross hatched area.

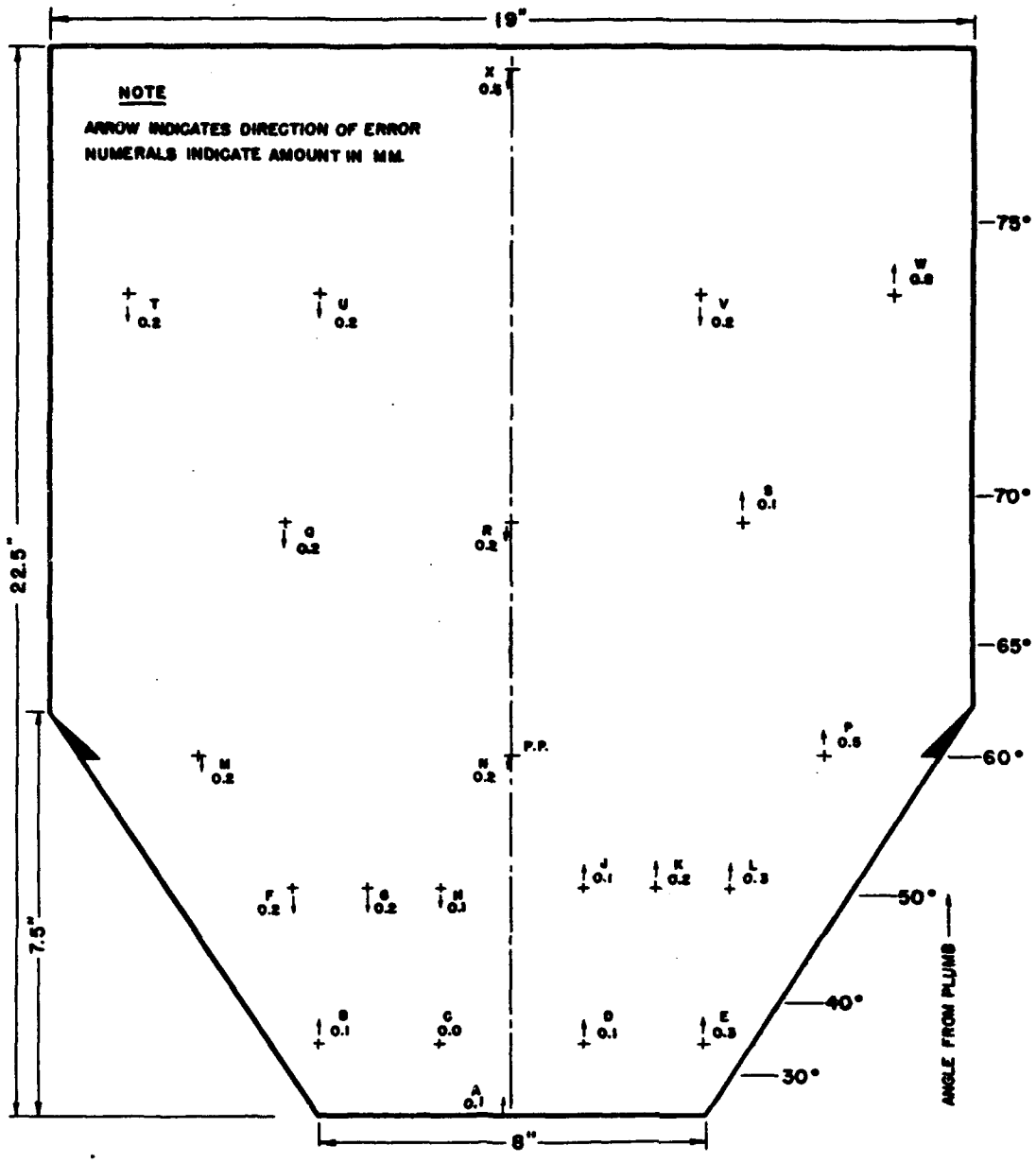


Fig. 21. Diagram showing accuracy of 60° rectification using modified Bausch and Lomb rectifier.

Table II. Radial and Tangential Lens Resolution at Two-diameter Magnification

Angle Orientation	0°		10°		20°		30°		40°	
	R	T	R	T	R	T	R	T	R	T
Resolution of 7-inch lens (lines per mm)	50	50	50	50	32	32	20	20	-	-
Resolution of 4½-inch lens (lines per mm)	50	50	50	50	40	40	25	25	20	20

b. Operational Characteristics. The instrument has been operated by personnel of the ERDL as well as by personnel of the Army Map Service, for the rectification of near vertical, split vertical, and tri-metrogon photography. These jobs included: (1) rectification of 79 tri-metrogon oblique negatives for the Aeronautical Chart Service; (2) rectification of 17 tri-metrogon oblique negatives to include 78½° from the vertical for the Aeronautical Chart Service; (3) rectification of 215 tri-metrogon oblique negatives by AMS for a shingle mosaic laydown; and (4) rectification of numerous split vertical and near vertical photographs for test purposes. The operational characteristics were determined from observations made during the actual production of rectified prints rather than by specific tests.

(1) Exposure Time. Fig. 23 indicates the approximate exposure times required for tri-metrogon obliques of average density. For a given print, the exposure time is affected by a number of variables such as tilt of negative, density of negative, number of fluorescent tubes used, lens stop, type of paper, and amount of hand dodging, so that the exact time required for any print must be determined to some extent through operator experience. In general, the exposure time was found to decrease as the angle of tilt was decreased, so that for near vertical photography it was in the neighborhood of 1 to 10 seconds.

(2) Print Quality. Appendix C is a sample of a contact print and one of a rectified print of a tri-metrogon oblique negative. The quality of the print is sufficient for either small-scale map compilation or mosaic assemblies with angles up to 70° from the plumb, and in some cases can be used with angles up to 75°.

(3) Rate of Production. Records of the work performed with this instrument show that an operator can rectify at least 32 prints per 8-hour day. Assuming the photography to

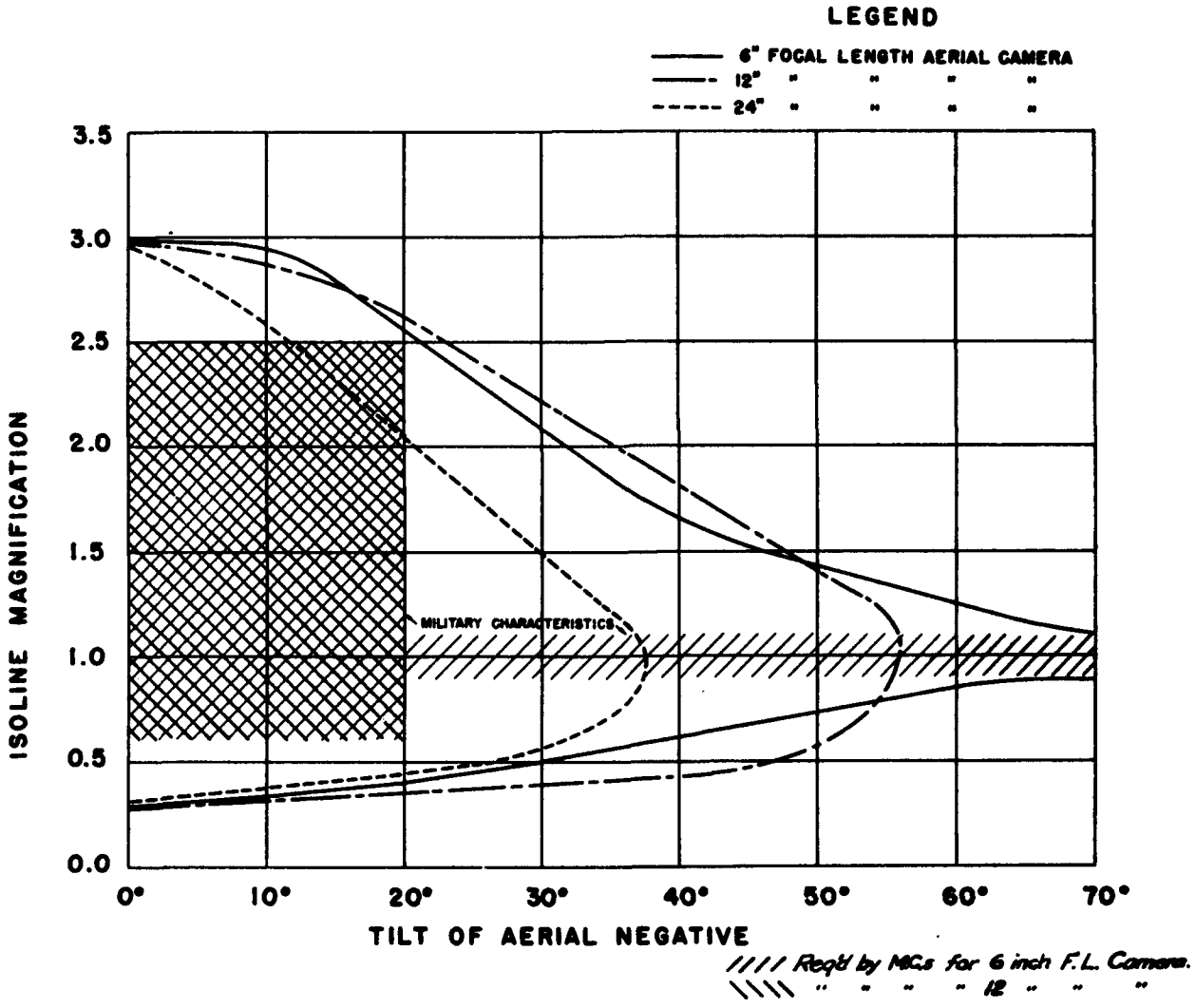


Fig. 22. Range of rectification of modified Bausch and Lomb rectifier.

be 6-inch focal length, flown at an altitude of 20,000 ft, with a tilt of 60° from the plumb, then a single rectified 20- by 24-inch print represents a ground coverage of approximately 170 square miles, and a strip of 32 consecutive rectified prints represents a ground coverage of approximately 1000 square miles, assuming the photographs were made such that the verticals contained an overlap of 60 percent, and that the rectified prints were used up to an angle of 75° from the plumb.

c. Road Tests. Road tests were carried out in two phases: 150 miles over good roads at speeds ranging from 30 to 50 mph; and 150 miles over secondary roads at speeds of 10 to 30 mph. At the conclusion of each phase, the instrument was checked for alignment and adjustment by projecting a perspective test grid onto the easel and comparing the image to its original size and shape prior to truck mounting. The results of these tests showed that there was no appreciable change in calibration or adjustment resulting from the truck tests. There were no mechanical failures in the instrument.

d. Low- and High-temperature Storage Tests. The rectifier was tested for storage under extreme temperature conditions by subjecting it to both low and high temperatures in the ERDL Temperature Test Chamber. For the low-temperature test, the temperature was reduced to -25, -50, and -80 F with an 8-hour soaking period at each of these temperatures. Including the time required to reduce the temperature of the test chamber, the instrument remained at subzero temperatures for a total period of 55 hours. For the high-temperature test, the temperature was raised to 165 F and was soaked for 8 hours at a relative humidity of 45 percent. In all, the instrument was subjected to above normal temperatures for a period of 15 hours. The instrument was examined for failures at -25, and -50 F as well as at the conclusion of both high- and low-temperature tests. There were no mechanical failures resulting from the low- and high-temperature storage tests.

e. Radio-interference Suppression Tests. The instrument was tested for radio interference by Signal Corps personnel from the Coles Signal Laboratory, Red Bank, N. J. Noise of an objectionable level was noted over the frequency range .35 through 156.0 megacycles using standard Signal Corps test equipment. The instrument was suppressed by means of line filters and capacitors, and by proper bonding to a suitable ground. Further tests showed that the suppression system attenuated, to a satisfactory level, radiated interference over the frequency range of .35 to 156.0 megacycles. Technical Memorandum M-1227, "Radio Interference Suppression of Rectifying Projection Printer," dated 26 September 1949, prepared by the Signal Corps Engineering Laboratories, Fort Monmouth, N. J., covers the suppression tests on this instrument.

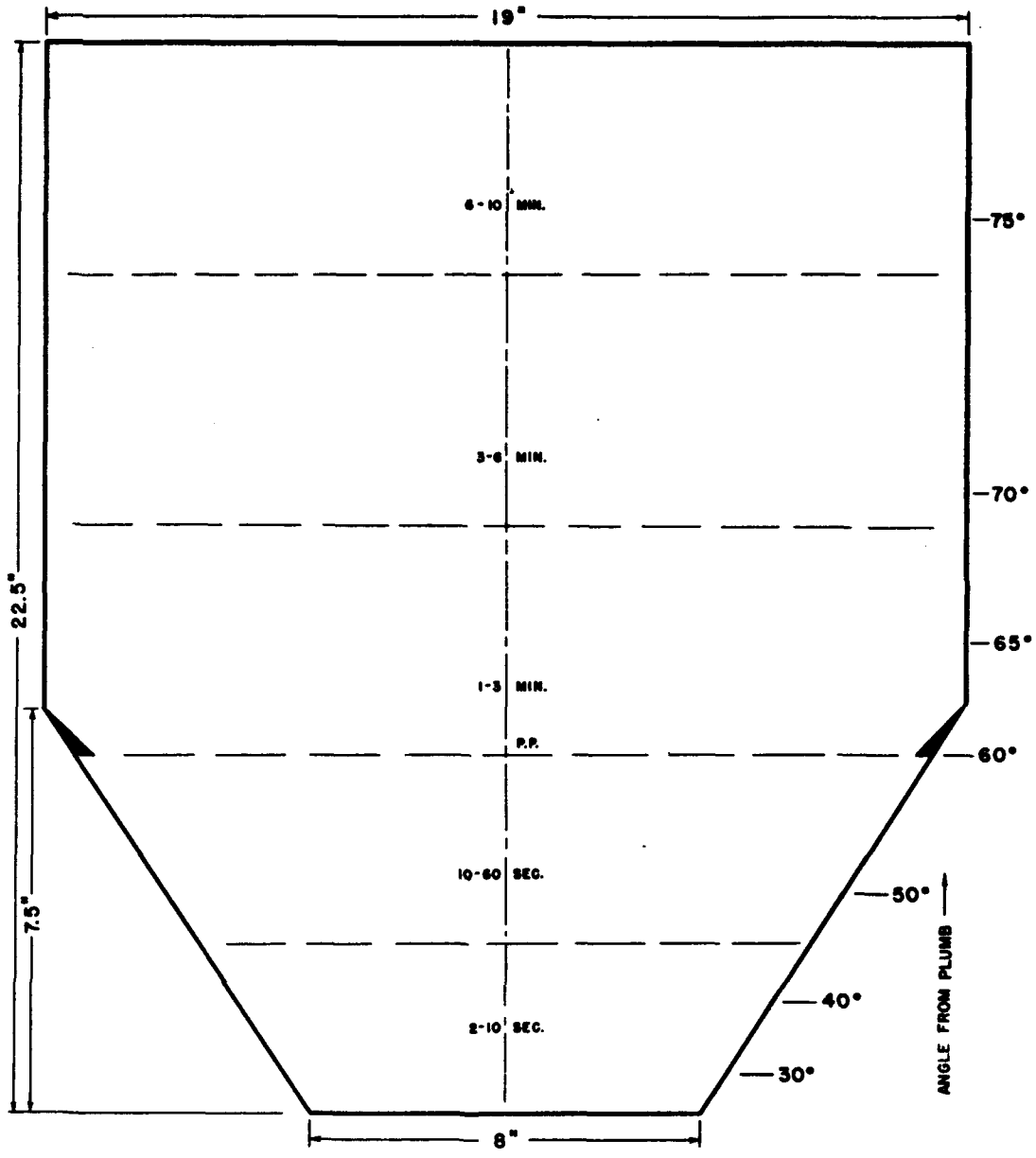


Fig. 23. Exposure time for tri-metrogon rectification using modified Bausch and Lomb rectifier.

f. Mildew and Fungus Resistance. Investigation of the resistance of the rectifier to mildew and fungus growth indicates that all parts of the instrument, except the projection lenses, are of a material covered by Federal specifications regarding treatment for resistance to fungus growth. At the present time, there is no satisfactory method for treating lenses of the type used in this instrument for permanent resistance to attack by fungus.

16. Drawings and Specifications. A complete set of detail drawings (D 7696) are currently being prepared for this equipment at the ERDL. Corps of Engineers specification titled, "Printer, Photographic, Horizontal Projection, Rectifying, Tilts under 70 Degrees, for 9½ Inch Aerial Roll Film," the standard nomenclature for this item, is also in the process of preparation.

III. DISCUSSION

17. Compliance with Military Characteristics. The engineering tests have shown that the modified Bausch and Lomb rectifier complies with the requirements of the approved military characteristics as listed in Appendix A. The instrument was also checked for compliance with those additional military characteristic requirements which are now standard for all types of military equipment. These include resistance to extreme temperature conditions, radio interference suppression, air portability, and mildew and fungus resistance. The engineering tests demonstrated that the instrument meets the requirements for extreme temperature conditions, and is satisfactorily suppressed to meet the radio interference suppression requirement. Weight and size are suitable for air transportability in any phase.

Investigation of the rectifier's resistance to mildew and fungus growth indicates that all parts of the instrument, except the projection lenses, are of a material covered by Federal specifications regarding treatment for resistance to fungus growth, and can be so treated in future procurement. At the present time, there is no satisfactory method for treating lenses of the type used in this instrument for permanent resistance to attack by fungus. As a consequence, it is proposed that the instrument be supplied with the lenses placed in a special tropical pack to protect them from fungus until the instrument is set up for use. When put in operation in regions where the lens will be attacked by fungus and mildew, it will be necessary to remove the lens periodically for a thorough cleaning, an operation that should require only a few minutes.

18. Operational Aids and Training Publications. Since the nomograms proved to be a more satisfactory aid to the calculation of settings than did the slide rule, because they cover the complete

range of the rectifier and provide more accurate results, complete sets of nomograms will be furnished with each instrument. The nomograms will be printed on a heavy paper base as this medium will satisfactorily withstand the temperature requirements. However, since the paper may tend to wear out and deteriorate with use, it is proposed that five complete sets of nomograms be furnished with each instrument.

The basic principles of the rectification process are set forth in TM-5-240. However, it will be necessary to prepare a technical manual on the operation and maintenance of the instrument.

19. Service Tests. Correspondence from Headquarters, Army Field Forces indicates that the results of engineering tests will be acceptable without subjecting the equipment to further service testing. A copy of this correspondence is contained in Appendix A to this report.

The engineering tests, to determine the suitability of the instrument for its intended service use, were conducted as operational tests, and consisted, for the most part, of the production rectification of tri-metrogon obliques. It is believed that this will be the major application of the instrument, in view of the prospective availability of the autofocus rectifying projection printer that was recently developed under a different project, especially for producing mosaic work from photography of lower tilts.[2] These production rectifications were performed by various personnel and, in all cases, the modified Bausch and Lomb rectifier satisfactorily performed the function for which it was developed.

The truck tests have demonstrated that the design of the instrument is suitable for withstanding the rough treatment of field use as there was no part breakage or other mechanical failure. In addition, the instrument retained its calibration throughout the tests and did not require readjustment because of wear or for any other reason.

20. Standardization. Since the modified Bausch and Lomb rectifier meets the requirements of the military characteristics, it is considered to be suitable for standardization as adopted type, standard type.

a. Basis of Issue. Vertical or near vertical mapping photography is normally preferred for mapping applications. Where it is desired to rectify such photography, the autofocus rectifier when standardized, should be suitable for this purpose. However,

2. ERDL Report 1124, Interim Report, Development of Autofocus Rectifying Projection Printer, 13 May 1949.

conditions may be such that near vertical photography is neither practical or possible to obtain, as was true in certain instances during the past war. In such instances, split vertical or trimetrogon photography was resorted to. Since the modified Bausch and Lomb rectifier is the only equipment which will accommodate the higher tilt photography, it is essential that this instrument be available to units when required. Consequently, it is proposed that the instrument be classified as a Class IV item for special issue. This classification is substantiated by correspondence from Headquarters, Army Field Forces shown in Appendix A.

b. Additional Information Required for Standardization. Additional information required for standardization together with the approved military characteristics is shown in Appendix B.

21. Personnel. Operation of the equipment breaks down into two categories: (1) determination of tilt angles and rectifier settings; and (2) printing the projected image of the negative. The Aerial Phototopographer, MOS (004), should be well qualified to perform the first task, while the Photographic Laboratory Technician, MOS (945), can perform the latter one. Appendix D shows a detailed description of these jobs.

IV. CONCLUSIONS

22. Conclusions. It is concluded that:

a. The modified Bausch and Lomb rectifier conforms to the requirements of the military characteristics for this development.

b. The modified Bausch and Lomb rectifier is suitable for standardization as adopted type, standard type, and as a Class IV item of supply.

c. Personnel normally assigned to topographic units are capable of operating the modified Bausch and Lomb rectifier.

V. RECOMMENDATIONS

23. Recommendations. It is recommended that:

a. The modified Bausch and Lomb rectifier be standardized as adopted type, standard type, and be stocked as a Class IV item of supply.

b. This project be closed.

Submitted by:

Frank A. McFarland

FRANK A. McFARLAND
Project Engineer

Forwarded by:

Gilbert G. Lorenz

GILBERT G. LORENZ
Chief, Photogrammetric Branch

Approved 13 March 1950 by:

William C. Cude

WILLIAM C. CUDE
Chief, Topographic Engineering
Department

APPENDIX A

AUTHORITY

Exhibit 1

SECURITY CLASSIFICATION UNCLASSIFIED

RESEARCH AND DEVELOPMENT PROJECT CARD (NON-PROJECTS) | a. SEC. U | b. NON-SEC. 8-35-03-001

1. PROJECT TITLE: RECTIFYING CAMERA | c. OCD PROJ. NO. MP488 | d. DATE ORIG. 30 Sept 47

4. BASIC FIELD OR SUBJECT: Mapping, Charting, and Geodesy

5. SUB FIELD OF SUBJECT AND GROUP: Photogrammetric Map and Chart Compilation

6. CONTRACT AGENCY: Office, Chief of Engineers

7. CONTRACTOR AND/OR LABORATORY: Engr. Res. & Dev. Laboratories Fred P. Willcox, Bethesda, Md.

CONTRACT/G. & NO.

8. DIRECTING AGENCY: Engr. Intell. Div., MO, OCE

10. SUPERVISING AGENCY: Office, Chief of Engineers

9. RELATED PROJECTS: 8-35-03-004

IV. EST. COMPL. DATES: MO. | QTR. June 48 | YEAR Jan 49 | OR ONLY Jan 50

11. PARTICIPATION AND/OR COORDINATION: Army Ground Forces (C)

14. DATE APPROVED: 28 March 1944 by ASF

V. FISCAL DATA: FY | 48 | 9 / 49 | 7 / T | 50

15. PRIORITY 2-A | 16.

18. ITEM NO. 1286, CETC Meeting 186

20. REQUIREMENT AND/OR JUSTIFICATION: A rectifying camera capable of rectifying aerial photography with tilts up to 70 degrees from the vertical is required to allow maximum utilization of tri-metrogon photography for reconnaissance mapping, charting and mosaic work. This development may result in a rectifier of such marked superiority over existing items that complete replacement would be justified.

21. BRIEF OF PROJECT AND OBJECTIVE

a. REFERENCES:

(1) Letter from the President, the Engineer Board to the Chief of Engineers dated 14 Jan 1944, Subject, "Transmittal of Engineer Board Report on Rectifying Projection Camera constructed at the Engineer Board", with 3 inclosures and 5 indorsements.

b. OBJECTIVE:

(1) Development of a rectifying camera in which is incorporated the range required for rectifying 6-inch focal length wide angle photography with tilts up to 70 degrees from the vertical and for rectifying 12 inch focal length photography with tilts up to 30 degrees.

c. MILITARY CHARACTERISTICS:

(1) The rectifier shall be capable of rectifying 9 inch by 9 inch aerial photography of approximately 6-inch focal length with tilts up to 70° from the vertical.

(2) The rectifier shall be capable of rectifying 9 inch by 9 inch aerial photography of approximately 12-inch focal length with tilts up to 30° from the vertical.

(3) The accuracy of the rectifier shall be such that the rectified prints produced therewith will be of sufficient accuracy for photogrammetric purposes.

(4) The rectifier shall have a magnification range of at least 0.9 to 1.1 when rectifying photography of high tilts and a magnification range of from 0.6 to 2.5 when rectifying photography with tilts up to 20°.

(5) The rectifier shall be of a type and size as small as possible to be consistent with good design. Weight of the instrument shall be held to a minimum consistent with the functions required.

22. JPRS | SEC. | PC. | IC & P. | T. | I. | C.

JROD FORM 12, 1 APR 1947 | WDGSD- | PAGE 1 OF 2 PAGES

SECURITY CLASSIFICATION UNCLASSIFIED

[redacted] | [redacted]

1. [redacted]
RECTIFYING CAMERA

[redacted]

e. MILITARY CHARACTERISTICS (Continued):

(6) The instrument shall be of all metal rigid construction.
(7) The rectifier shall have interchangeable lenses, one of which shall be of approximately 4½-inch focal length and suitable for rectifying the 9 inch by 9 inch six-inch photography with high tilts. The other lens shall be of approximately 8-inch focal length and suitable for use in rectifying the 9 inch by 9 inch, twelve-inch focal length photography and the six-inch photography of low tilts.
(8) The rectifier shall be equipped with suitable scales by means of which the rectifier may be set to predetermined data and these scales shall be such that the computations necessary for determining their settings are reduced to a minimum. Aids to the determinations of settings where computation is necessary, such as nomograms, charts or curves will be furnished with the instrument.
(9) The easel shall be of the vacuum frame type and no larger than necessary to accommodate the rectifications and/or enlargements specified above.
(10) The light source shall be of standard fluorescent tubes.
(11) The rectifier shall be so constructed that easy access may be had to the negative stage without dismantling any part of the instrument, for the purpose of changing and orienting negatives.
(12) The rectifier shall take both roll and cut film.
(13) The design and construction of the instrument shall be as simple as possible consistent with the requirements.
(14) The construction shall contain a minimum of strategic and critical materials consistent with the functions required.
(15) Adequate instructions for assembly, operation and maintenance shall be furnished with the instrument.
(16) The rectifier shall be so designed that it can be dismantled in sections for packing in 2 or 3 carrying chests.

d. DISCUSSION:
(1) Reference a (1) transmits report on preliminary work of Engineer Board on a rectifying camera and recommends opening development project. Fourth indorsement from Hq., Army Service Forces to Chief of Engineers dated 28 March 1944 approves project and military characteristics.
(2) Agencies interested in this project, in addition to the Office, Chief of Engineers, are Army Ground Forces, Department of the Air Force and Hydrographic Office, Department of the Navy.

e. PROJECT PLAN:
(1) Two pilot machines have been obtained and subjected to extensive engineering tests, which indicate that one, with modifications, probably will meet military requirements.
(2) The most promising pilot model will be modified to remedy defects disclosed by engineering tests.
(3) The modified pilot model will be subjected to further engineering tests and then to service tests by interested agencies.
(4) Plans and specifications of the final model will be prepared and recommendations submitted to the Chief of Engineers regarding classification of equipment action, basis of issue and existing production facilities.

[redacted] PAGE 2 OF 2 PAGES

Exhibit 2

SUBJECT: Transmittal of Service Test Card on Rectifying Camera, Project 8-35-03-001

ENGIE (19 Apr 49) 2nd Ind

Office of the Chief of Engineers, Washington 25, D. C., 4 October 1949

TO: Commanding General, The Engineer Center, Fort Belvoir, Virginia

1. Reference is made to letter dated 16 August 1949, ENGIE to Chief, Army Field Forces, subject: "Service Test of Printer, Photographic, Horizontal Projection, Rectifying, Tilts under 70 Degrees, 9-1/2 Inch Roll Film, Project 8-35-03-001," with three indorsements, copies of which are inclosed.

2. The Army Field Forces indicate in the reference correspondence that results of engineering tests of the subject equipment will be acceptable without subjecting it to further service testing, and recommend that it be classified as a Class IV item for special issue.

3. In view of the above, the item has, by mutual agreement with the Engineer Research and Development Laboratories, been deleted from the Engineer Service Test Procurement Program for 1950 and proposed action for establishment of a Service Test Project for the item has been canceled.

4. It is proposed that classification action and termination of Project 8-35-03-001 be initiated as soon as practicable. However, prior to proceeding with the above action, completion and submission of the following are required of the Engineer Research and Development Laboratories:

a. Final report on Development Project 8-35-03-001, Rectifying Camera.

b. Procurement specifications and/or drawings.

BY ORDER OF THE CHIEF OF ENGINEERS:

3 Incls
1. Subcommittee Memo
2. Draft of Proposed ST Card

Added:
3. Cy ltr, 16Aug 49, ENGIE to Ch/AFF w/3 Inds

D. G. HAMMOND
Lt. Colonel, Corps of Engineers
Chief, Engr Research & Development Div
Military Operations

ATTEC-Eng 413.5(16 Aug 49) 3rd Ind
Subject: Service Test of Printer, Photographic, Horizontal Projection, Rectifying, Tilts under 70 Degrees 9 1/2 Inch Roll Film, Project 8-35-03-001

Office, Chief, Army Field Forces, Fort Monroe, Virginia, 20 Sep 49

TO: Chief of Engineers, Department of the Army,
ATTN: Engineer Research and Development Division

1. With reference to paragraph 4 of the basic correspondence, Army Field Forces will accept the results of the engineering tests of the subject equipment without subjecting it to further service testing.

2. At the present time there is no firm T/O&E requirement for this item by AFF units. It is recommended that it be classified as a Class IV item for special issue pending clarification of T/O&E requirement.

FOR THE CHIEF, ARMY FIELD FORCES:

/s/ Frank W. Roberts
FRANK W. ROBERTS
Lt Col AGD
Asst Adj Gen

ATTEC-Eng 413.5(16 Aug 49) 1st Ind
Subject: Service Test of Printer, Photographic Horizontal Projection, Rectifying, Tilts under 70 Degrees, 9 1/2 Inch Roll Film, Project 8-35-03-001

Office, Chief of Army Field Forces, Fort Monroe, Va., 23 Aug 49

TO: President, AFF Board No. 2, Fort Knox, Kentucky

The basic correspondence is forwarded for your comments and recommendations relative to the desirability of further service testing of the subject equipment by AFF.

FOR THE CHIEF, ARMY FIELD FORCES:

/s/ Neil M. Matzger
NEIL M. MATZGER
Lt. Col AGD
Asst Adj Gen

AKCE 413.53 (16 Aug 49) 2nd Ind
Subject: Service Test of Printer, Photographic Horizontal Projection, Rectifying, Tilts under 70 Degrees, 9 1/2 Inch Roll Film, Project 8-35-03-001

Army Field Forces, Board No. 2, Fort Knox, Kentucky, 8 Sep 49

TO: Chief, Army Field Forces, Fort Monroe, Virginia
ATTN: Assistant Chief for Developments

Subject equipment is of such a nature that thorough engineering tests fulfill the requirements of field tests. After conference with personnel of the Engineer Research and Development Laboratories this board believes that their engineering test should be accepted and that no service tests should be undertaken by Army Field Forces.

FOR THE PRESIDENT:

/s/ S. G. Brown, Jr.
S. G. BROWN, JR.
Lt Col, Cav
Executive

ENGIE 16 August 1949

SUBJECT: Service Test of Printer, Photographic Horizontal Projection, Rectifying, Tilts under 70 Degrees, 9½ Inch Roll Film, Project 8-35-03-001

TO: Chief, Army Field Forces
Fort Monroe, Virginia

1. Reference is made to 8th Indorsement, dated 2 March 1949, file ATTEC-Eng 413.53 (25 Oct 48), from the Chief, Army Field Forces to Chief of Engineers, above subject, requesting that your office be notified when a model of the subject printer becomes available for service tests.

2. The subject item of equipment has undergone complete and thorough engineering tests at the Engineer Research and Development Laboratories and meets the requirements of the military characteristics except that the lens is not fungi-proofed. At the present there is no satisfactory method for treating lenses of the type used in this instrument for permanent resistance to attach by fungi. In addition to the military characteristics stated on Project Card No. 8-35-03-001, the subject printer will also meet the present general requirements for operation and storage under extreme temperatures and for radio suppression.

3. It is the opinion of this office that standardization of this equipment could proceed without further extended tests by the Army Field Forces. It is believed that it should be classified as a Class IV item for special issue if the requirements for issue to all topographic units are not firm at this time.

4. Confirmation of the desire of Army Field Forces to service test the subject rectifying printer in view of the above comments is requested.

FOR THE CHIEF OF ENGINEERS:

D. G. HAMMOND
Lt. Colonel, Corps of Engineers
Acting Chief, Engr Res & Dev Div
Military Operations

APPENDIX B

INFORMATION REQUIRED FOR STANDARDIZATION

INFORMATION REQUIRED FOR STANDARDIZATION

Information required for classification of a new item of equipment is given below:

1. Approved Military Characteristics. The approved military characteristics for the Printer, Photographic, Horizontal Projection, Rectifying are as follows:

a. The rectifier shall be capable of rectifying 9 inch by 9 inch aerial photography of approximately 6-inch focal length with tilts up to 70° from the vertical.

b. The rectifier shall be capable of rectifying 9 inch by 9 inch aerial photography of approximately 12-inch focal length with tilts up to 30° from the vertical.

c. The accuracy of the rectifier shall be such that the rectified prints produced therewith will be of sufficient accuracy for photogrammetric purposes.

d. The rectifier shall have a magnification range of at least 0.9 to 1.1 when rectifying photography of high tilts and a magnification range of from 0.6 to 2.5 when rectifying photography with tilts up to 20°.

e. The rectifier shall be of a type and size as small as possible to be consistent with good design. Weight of the instrument shall be held to a minimum consistent with the functions required.

f. The instrument shall be of all metal rigid construction.

g. The rectifier shall have interchangeable lenses, one of which shall be of approximately 4½-inch focal length and suitable for rectifying the 9 inch by 9 inch six-inch photography with high tilts. The other lens shall be of approximately 8-inch focal length and suitable for use in rectifying the 9 inch by 9 inch, twelve-inch focal length photography and the six-inch photography of low tilts.

h. The rectifier shall be equipped with suitable scales by means of which the rectifier may be set to predetermined data and these scales shall be such that the computations necessary for determining their settings are reduced to a minimum. Aids to the determinations of settings where computation is necessary, such as nomograms, charts or curves will be furnished with the instrument.

i. The easel shall be of the vacuum frame type and no larger than necessary to accommodate the rectifications and/or

enlargements specified above.

j. The light source shall be of standard fluorescent tubes.

k. The rectifier shall be so constructed that easy access may be had to the negative stage without dismantling any part of the instrument, for the purpose of changing and orienting negatives.

l. The rectifier shall take both roll and cut film.

m. The design and construction of the instrument shall be as simple as possible consistent with the requirements.

n. The construction shall contain a minimum of strategic and critical materials consistent with the functions required.

o. Adequate instructions for assembly, operation and maintenance shall be furnished with the instrument.

p. The rectifier shall be so designed that it can be dismantled in sections for packing in 2 or 3 carrying chests.

2. Dimensions and Weight. Dimensions and weight of the complete Printer, Photographic, Horizontal Projection, Rectifying with cases are as follows:

a. Dimensions.

1. Chest No. 1 -- 5 ft 4" x 3 ft 2" x 1 ft 5"
2. Chest No. 2 -- 3 ft 3" x 2 ft 2" x 2 ft 0"

b. Weight 590 pounds.

3. Cost to Fabricate Single Unit. Estimated cost of production of one complete Printer, Photographic, Horizontal Projection, Rectifying, $8000.00.

4. Cost in Quantity Production. Estimated cost of the Printer, Photographic, Horizontal Projection, Rectifying, in quantity production of 10 or more is $5500.00 per unit.

5. Production Data. It is estimated that an established manufacturer such as the Bausch and Lomb Optical Company could initiate production of the Printer, Photographic, Horizontal Projection, Rectifying in 60 days and could produce 10 complete units in the next 6 months thereafter.

6. Overseas Use. The Printer, Photographic, Horizontal Projection, Rectifying is satisfactory from a development point of view for use overseas.

7. Standardization and Interchangeability of Parts. The design of the Printer, Photographic, Horizontal Projection, Rectifying does accomplish the objectives of maximum standardization and interchangeability of parts.

8. Spare Parts List. The following is a list of first echelon spare parts for the Printer, Photographic, Horizontal Projection, Rectifying:

Item	Quantity
Stage Plate	1
Pressure Plate	1
Fluorescent Tubes, 12 inch, 8-watt (T-5)	14
Neon Glow Lamps, NE 45, ¼W. (T-4 ½ Cand. Screw Base)	9
Neon Glow Lamps, NE 30, 1W. (G 10 Med Screw Base)	1
Starters, FS-5, for 8-watt, 12-inch fluorescent tubes	6

APPENDIX C

ILLUSTRATION OF

TRI-METROGON RECTIFICATION

3925 ARMY FORT BELVOIR VA 4-25-50

APPENDIX D

MILITARY OCCUPATIONAL SPECIALTIES

MILITARY OCCUPATIONAL SPECIALTY

No. (004) AERIAL PHOTOTOPOGRAPHER

Uses aerial photographs in the construction of planimetric and topographic maps, aeronautical charts, and controlled and uncontrolled mosaics.

Makes mathematical computations in connection with the construction of tables and graphs to correct calculations for distortion in photographs and stereographic displacements. Constructs control boards upon which mosaics are assembled and makes planimetric maps for use in constructing topographic maps with stereocomparagraph.

Must be familiar with conventional signs and symbols used in military mapping. Ability to interpret aerial photographs essential.

Must be experienced in topographic drafting.

MILITARY OCCUPATIONAL SPECIALTY

No. (945) PHOTOGRAPHIC LABORATORY TECHNICIAN

Performs a variety of tasks in connection with photographic processing in a military photographic laboratory.

Prepares and mixes photographic solutions, following prescribed formula. Develops film by immersing them for prescribed periods at specified temperatures in prepared chemical solutions. Makes contact and projection prints by means of printing machine, placing sensitized paper over negative and exposing the prints to electric light, removes prints from machine, develops them in chemical solutions, and dries them. In Army Air Force, assembles uncontrolled mosaic strips, makes reproduction photographs by use of standard copy cameras or other ground cameras and equipment.

May spot or retouch photographic prints and negatives, using retouching fluid, knives, and pencils.

At supervisory level, is responsible for control and coordination of laboratory personnel and equipment.

Must be thoroughly familiar with photographic laboratory equipment such as film developers, film driers, and print driers. Must be familiar with various types of sensitized materials, print washers, and other chemicals used in connection with photographic work.

APPROVAL OF

Report 1161

PRINTER, PHOTOGRAPHIC, HORIZONTAL PROJECTION,

RECTIFYING, TILTS UNDER 70°,

FOR 9½-INCH AERIAL ROLL FILM

13 March 1950

and

DISTRIBUTION

ENGINEER RESEARCH AND DEVELOPMENT LABORATORIES
THE ENGINEER CENTER AND FORT BELVOIR
FORT BELVOIR, VA.

ADDRESS REPLY TO
COMMANDING OFFICER
ENGINEER RESEARCH AND DEVELOPMENT LABORATORIES
FORT BELVOIR, VA.

1 JUN 1950

IN REPLY REFER TO: TECHD ASI
400.1 (8-35-03-001)

SUBJECT: Transmittal of Report 1161, Final Report, Printer, Photographic, Horizontal Projection, Rectifying, Tilts Under 70°, for 9½-Inch Aerial Roll Film

THRU: Commanding General
The Engineer Center and Fort Belvoir
Fort Belvoir, Virginia

TO: Chief of Engineers
Department of the Army
Washington 25, D. C.
ATTENTION: Chief, Engineer Research and Development Division

1. Transmitted herewith is Report 1161, "Final Report, Printer, Photographic, Horizontal Projection, Rectifying, Tilts Under 70°, for 9½-Inch Aerial Roll Film," dated 13 March 1950, which was prepared by the Technical Staff of the Engineer Research and Development Laboratories. This report covers an investigation involving the development, testing, and standardization of a lightweight, portable, horizontal, rectifying projection printer, mounted in a truck or trailer, for use in rectifying 9- by 9-inch, 6-inch focal length photography with tilts up to 70°, and 9- by 9-inch, 12-inch focal length photography with tilts up to 30° from the vertical.

2. The report concludes that:

a. The modified Bausch and Lomb rectifier conforms to the requirements of the military characteristics for this development.

b. The modified Bausch and Lomb rectifier is suitable for standardization as adopted type, standard type, and as a Class IV item of supply.

c. Personnel normally assigned to topographic units are capable of operating the modified Bausch and Lomb rectifier.

TECRD ASI
400.1 (8-25-03-001)
Subject: Transmittal of Report 1161, Final Report, Printer, Photographic, Horizontal Projection, Rectifying, Tilts Under 70°, for 9½-Inch Aerial Roll Film

3. The report recommends that:

a. The modified Bausch and Lomb rectifier be standardized as adopted type, standard type, and be stocked as a Class IV item of supply.

b. This project be closed.

4. The report with its conclusions and recommendations is approved.

O. B. BEASLEY
Colonel, CE
Commanding

2 Incls
1. Proposed distr list (in quint)
2. Rpt 1161 (in quad)

SPTR 400.1 1st Ind

Hq, The Engr Con Bd, Ft Belvoir, Ft Belvoir, Va. 1 JUN 1950

TO: C of Engrs, DA, Washington 25, D. C.

2 Incls
N/C

SUBJECT: Transmittal of Report 1161, Final Report, Printer, Photographic, Horizontal Projection, Rectifying, Tilts Under 70°, for 9½ Inch Aerial Roll Film

ENGIE (1 Jun 50) 2nd Ind

Office of the Chief of Engineers, Washington 25, D. C., 14 Jun 50

TO: Commanding General, The Engineer Center, Fort Belvoir, Va.

1. The subject report and proposed distribution are approved.

2. With reference to recommendations in paragraphs 3a and 3b of the basic letter, necessary action in connection with classification of the subject item and closing of Project 8-35-03-001 will be initiated and presented at an early date for Corps of Engineers Technical Committee action.

BY ORDER OF THE CHIEF OF ENGINEERS:

D. G. Hammond

1 Incl
1. Proposed Distr List
(Incl No. 2 w/d)

D. G. HAMMOND
Lt. Colonel, Corps of Engineers
Chief, Engr Research & Development Div
Military Operations

TECAG 400.1 3rd Ind

Hq, The Engr Cen & Ft Belvoir, Ft Belvoir, Va. 19 JUN 1950

TO: CO, E.R.D.L., Ft Belvoir, Va.

Tchnel
VC

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